# SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

The JOURNAL of the FEDERATION OF SEWAGE WORKS ASSOCIATIONS

## *Special Features*

Sanitary Engineering Progress—Fair

Sewage Chlorination—Eliassen and Kreiger

Biological Treatment of SWL—Holderby

Wool Scouring Wastes—McCarthy

JANUARY, 1950—VOL. 22, No. 1

# *Notice to all Active Members of Member Associations*

Your prompt payment of 1950 dues will avoid interruption in receipt of SEWAGE AND INDUSTRIAL WASTES as well as other Federation services. Undue delay may make it impossible for a complete volume of the JOURNAL to be furnished.

Please remit immediately upon receipt of the first dues notice from your Member Association Secretary.

FEDERATION OF SEWAGE WORKS ASSNS.
325 Illinois Bldg. Champaign, Ill.

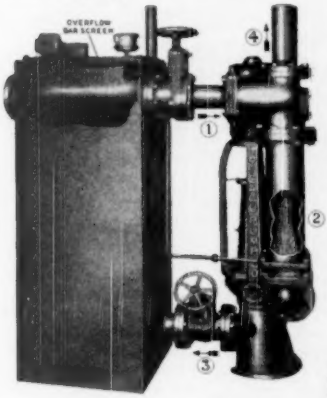
# CHICAGO" PUMPS

## FOR SEWAGE AND SLUDGE

### *FLUSH KLEEN EJECTORS FOR SEWAGE*

"Flush Kleen" pumps provide automatic, trouble-free service in sewage lift-stations. They require no manual attention except periodic lubrication and inspection. No labor is required for disassembling and cleaning clogged pumps as with other types.

The impellers handle only strained sewage. No solids pass through the impeller to cause excessive strain and wear on impeller, shaft, bearings or motor; pumps remain in balance and operate economically with little attention.

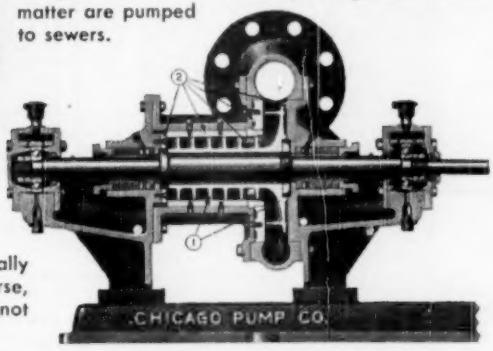



**Filling Wet Well**

1. Sewage flows through inlet pipe.
2. Coarse matter is retained on strainer.
3. Strained sewage flows through idle pump to wet well.

**Pumping**

3. Strained sewage is pumped from wet well.
2. Coarse matter is backwashed from strainer.
4. Special check valve closes; sewage and coarse matter are pumped to sewers.




## SCRU-PELLER PUMPS FOR SLUDGE

The Scru-Peller Pump was specifically designed to handle sludge. Coarse, stringy material is cut and cannot wrap or bind the impellers.

**1 SCREW and IMPELLER** are keyed on the shaft and held firmly against a shoulder on the shaft by a nut. The screw has two flights; and the impeller has two blades. Each flight in the conveyor connects directly with its own blade of the impeller.

**2 CUTTING EDGES.** There are four cutting bars and a cutting ring in the screw housing and four cutting bars in the pump casing. The cutting takes place between the edges of the screw and the cutting edges in the screw housing, between the edges of the impeller blades and the cutting edges in front of the impeller, and between the edges of the impeller blades on the back of the impeller and the cutting edges of the pump casing.

## CHICAGO PUMP COMPANY

**SEWAGE EQUIPMENT DIVISION**

**2300 WOLFRAM STREET** — Flush Kleen, Scru-Peller, Plunger, Horizontal and Vertical Non-Clogs Water Seal Pumping Units, Samplers.

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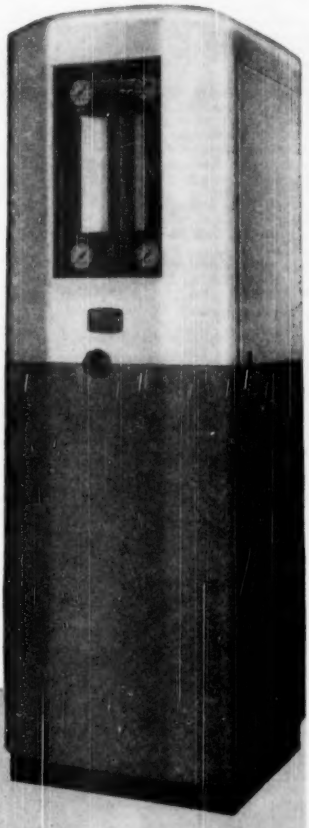

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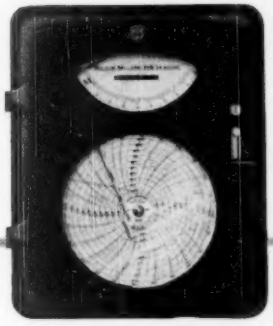


## With New TYPE "H" METER

**An extremely accurate meter which measures flows within ± 2% over a 13 to 1 range!**

We feel that a discerning engineer requires accuracy above all else in any instrument he purchases. Within its flow range the new Type "H" Meter registers measurements that are more accurate than usually encountered in commercial instrumentation and it truly "narrows the gap of error".

Type "H" Meter is specially designed for:

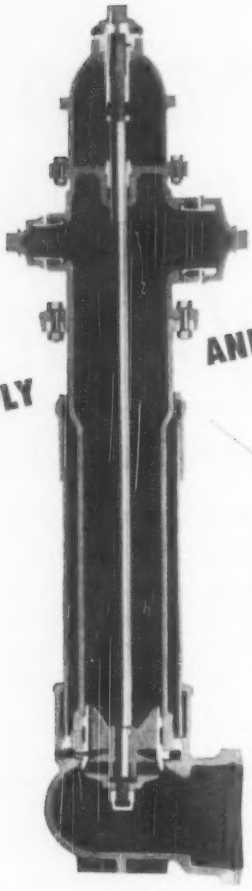
- **Use with Venturi Tube, Flow Nozzle, or Orifice Plate.**
- **Measurement of hot or cold water, steam, process liquors, gases, trade wastes, sewage or sludge.**
- **Wall bracket, instrument panel, or floor mounting . . . outdoor or indoor as desired.**
- **Inclusion of three vital measuring elements—indicator, recorder, totalizer.**
- **Testing in place at any time with an easily applied manometer test device.**
- **Maximum differentials of 114" or 64" of water as desired.**
- **Easy flow reading, utilizing evenly spaced chart and dial graduations.**

IT'S ACCURATE IT'S SIMPLEX

Write for Free Bulletin No. 400 to the Simplex Valve & Meter Co., Dept. 1, 6719 Upland St., Philadelphia 42, Pa.

**SIMPLEX**

**VALVE AND METER COMPANY**



SIMPLY AND SOUNDLY CONSTRUCTED

Simplicity of construction pays off in dependability and ease of maintenance.

**Mathews Modernized Hydrants Set the Pace:** All working parts contained in replaceable barrel • Stuffing box cast integral with nozzle section • Head can be turned 360° • Replaceable head • Nozzle outlets easily changed • Nozzle levels raised or lowered without excavating • Protection case of "Sand-Spun" cast iron for extra strength, toughness, elasticity • Operating thread only part to be lubricated • A modern barrel makes an old Mathews good as new

# MATHEWS HYDRANTS

THE FIREMAN'S FRIEND

**Made by R. D. Wood Company**

**Public Ledger Building, Independence Square**

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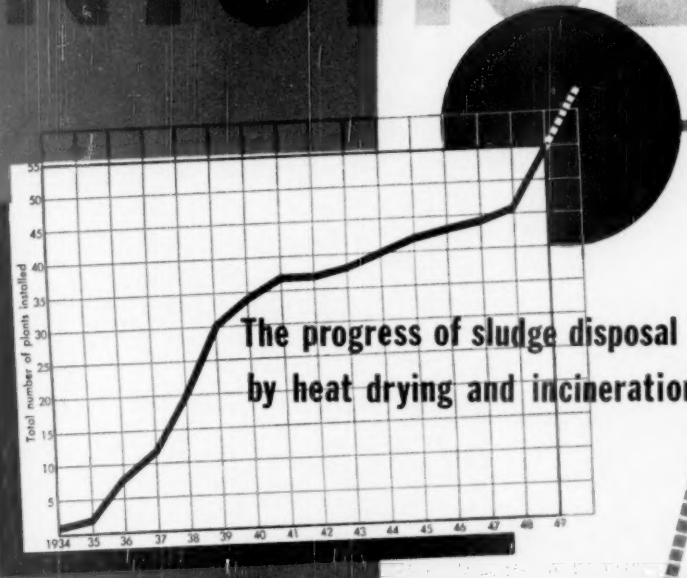
Manufacturers of "Sand-Spun" Pipe (centrifugally cast in sand molds) and R. D. Wood Gate Valves.

# NICHOLS RECORD OF CONTINUOUS PROGRESS




The progress of sludge disposal by heat drying and incineration

ANN ARBOR, MICH. . . . April 1949

BRIDGEPORT, CONN. East Plant May 1949

AKRON, OHIO . . . . May 1949

PROVIDENCE, R.I. . . . June 1949

BRIDGEPORT, CONN. West Plant Nov. 1949

These cities made two important decisions during 1949 in solving their sewage sludge disposal problems, by specifying heat drying and incineration as the best methods and Nichols Multiple Hearth Incinerators as the best means.

WHY?

*Low initial cost · Compact disposal plant*
*Economy of operation*

NICHOLS — *the foremost name in incineration.*

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**. . . NOW REDESIGNED FOR STILL HIGHER EFFICIENCY**

If you're pumping solids . . . not large enough to require regular non-clog slow speed sewage pumps . . . you'll find Economy volute mixed flow pumps the answer to your problem. Engineered for greater economy in operation, the Economy mixed flow volute line, tested and proved in twenty-two years of operation, has now been redesigned for still higher efficiency.

Built to keep pumping longer at lower cost these pumps are equipped with the highest duty bearings available, including double row, angular contact thrust bearing. Large size pumps also have a self-aligning, spherical roller radial bearing.

Capacities range from 3,000 to 50,000 G.P.M., heads from 10 to 50 ft. For complete details, write Dept. AC-1.

**Centrifugal, axial and mixed flow pumps for all applications.**

**Economy Pumps Inc.**

DIVISION OF HAMILTON-THOMAS CORP., HAMILTON, OHIO

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# Tightness

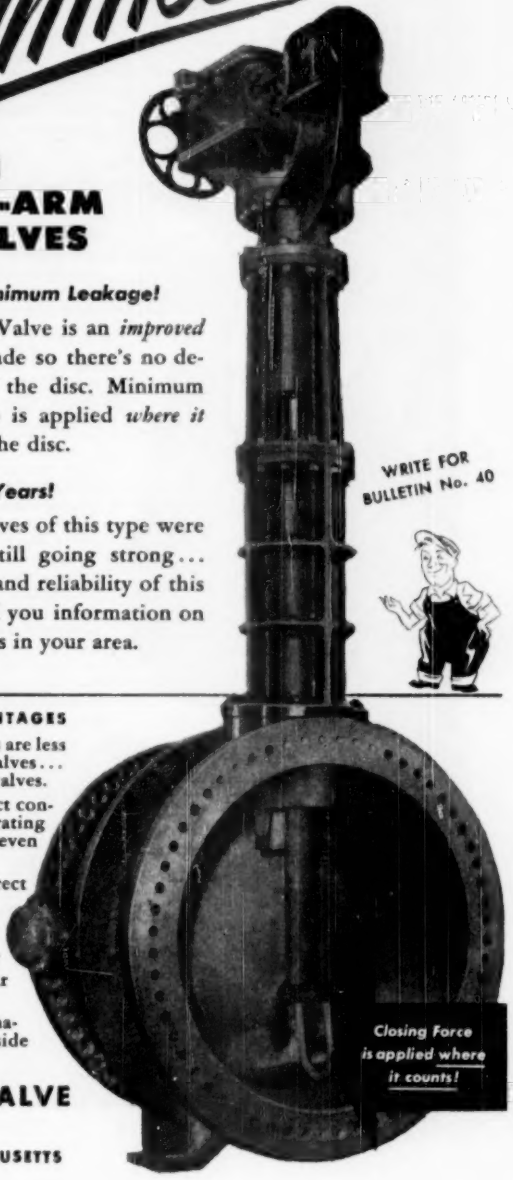
WITH
DOW DISC-ARM
PIVOT VALVES

***No Deflection of Disc! Minimum Leakage!***

This Dow Disc-Arm Pivot Valve is an *improved type* of butterfly valve. It's made so there's no deflection of the lower half of the disc. Minimum leakage. The operating force is applied *where it should be*... at the bottom of the disc.

***Tested for 25 Years!***

More than 25 years ago, valves of this type were first installed. And they are still going strong... proving the unusual strength and reliability of this design. We'll be glad to send you information on the location of the installations in your area.




WRITE FOR
BULLETIN No. 40



**NOTE THESE OTHER ADVANTAGES**

***Low Head Losses!*** Head losses are less than for needle or plunger type valves... only slightly higher than gate valves.

***No Vibration!*** Because of direct connection between disc and operating mechanism there is no vibration even at highest velocities.

***Speed Closing!*** Simple and direct operation gives quick closing in emergencies...only one-half the pipe diameter to travel.

***Smooth Operation!*** None of the jerkiness... none of the wear of valves with sliding seats.

***Easy Inspection!*** Disc mechanism is on the downstream side when valve is closed.

**THE CHAPMAN VALVE MFG. CO.**
INDIAN ORCHARD, MASSACHUSETTS

# "Hey, Joe! Did you ever see a $100 bolt?"

**JOE:** "What d'ya mean, a hundred-dollar bolt?"

**GUS:** "Just what I said. We're raising Number 3 Gate just now and this anchor bolt let go."

**JOE:** "But we put that gate in less than two years ago, and . . ."

**GUS:** "Yeah, I know. But we used ordinary bolts and this one's already rusted through. It'll cost at least a hundred bucks to take that gate out, dig the old bolt out of the concrete and set a new one in."

**JOE:** "I guess it will. But from here out we don't make that mistake twice. From now on everything that goes in is Everdur."

Most sewage and waterworks engineers have discovered that the most economical way to lick the corrosion problem in their plants is to use Everdur*—ANACONDA's copper-silicon group of alloys. There are plants where equipment made of Everdur has been doing it for over 22 years.

If you don't already know about Everdur, let us tell you about its high strength, durability and how easy it is to fabricate it into lightweight, low-cost wrought assemblies. Just ask for the Everdur booklets. Let our Technical Department counsel you on any special problems or applications. Write to The American Brass Company, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario. 491-70

**Where corrosion resistance counts—use Everdur**

**ANACONDA**
**copper-silicon alloys**

*Reg. U.S. Pat. Off.

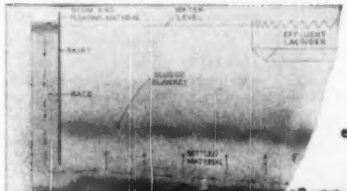
# Operating results attest overall efficiency . . . . . of →

YEOMANS *Spiraflo* CLARIFIER with tangential inlet

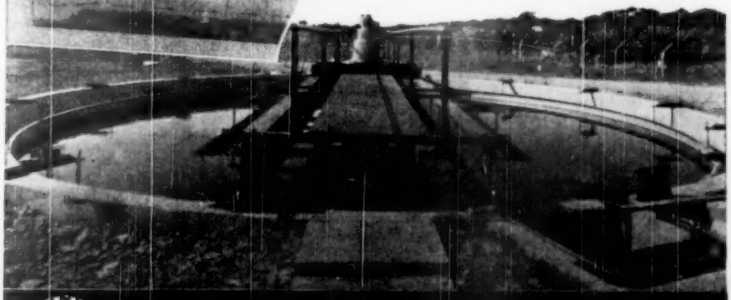
Radically different from other types of clarifiers, Yeomans Spiraflo Clarifier is demonstrating in scores of installations its exceptional efficiency in BOD and solids removal—results directly attributable to these design features:

- Sewage enters the main clarification compartment at the bottom, after having spiraled through an annular race around the periphery of the tank
- Scum, grease oil and floatable materials are automatically removed from the annular race—therefore cannot pass on to the filter and clog distributor nozzles
- Raw sewage flows upward through a sludge blanket toward centrally located effluent weirs—increases flocculation and removal of solids
- Construction costs are minimized because of straight-wall design and elimination of costly reinforced concrete effluent troughs
- Pre-aeration can be accomplished inexpensively by installing air diffusion tubes in the race

Spiraflo clarifiers can be installed in water treatment and in either trickling filter or activated sludge sewage treatment plants. A highly efficient overall plant reduction is achieved when the Spiraflo is used in conjunction with the "Aero-Filter" high capacity trickling filter system. Spiraflo clarifiers are the logical choice for primary treatment plants, especially those treating strong industrial wastes.



Bulletin 6790 contains full information with performance data and construction cost estimates—write us for it.



YEOMANS

YEOMANS BROTHERS COMPANY, 1411 North Dayton Street, Chicago 22, Illinois

## for replacements or new installations

# Specify CLOW

CAST IRON PIPE, FITTINGS, VALVES and SPECIALS In Sewage Plant Construction

**ASSURED LONG LIFE**

*for a century or more*

**CLOW BELL END SLUDGE SHOE**— Also comes with Flanged End. Improved Sludge Shoes are extra strong, have maximum sludge opening, and the flare reduces entrance losses to a minimum.

**CLOW PRESSURE RELIEF VALVES** – Bronzed mounted for smooth operation. Made with grated bottom to allow water only to enter tank. Can be made to any length desired.

**CLOW FLANGED END FLAP VALVE**— Also comes with Bell or Spigot End. Flap valves are bronze mounted, are superior in meeting most field conditions, may be easily dismounted for repairs if found necessary at any time.

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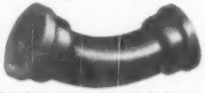

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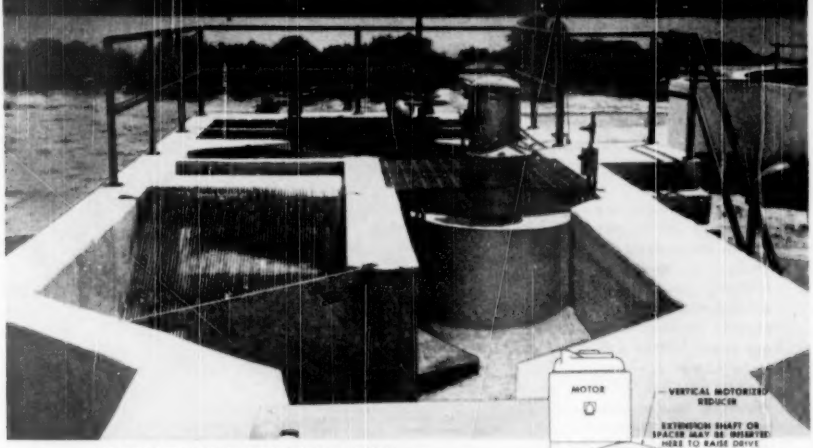

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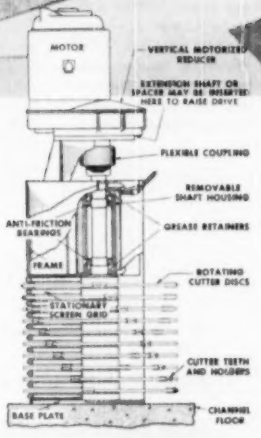


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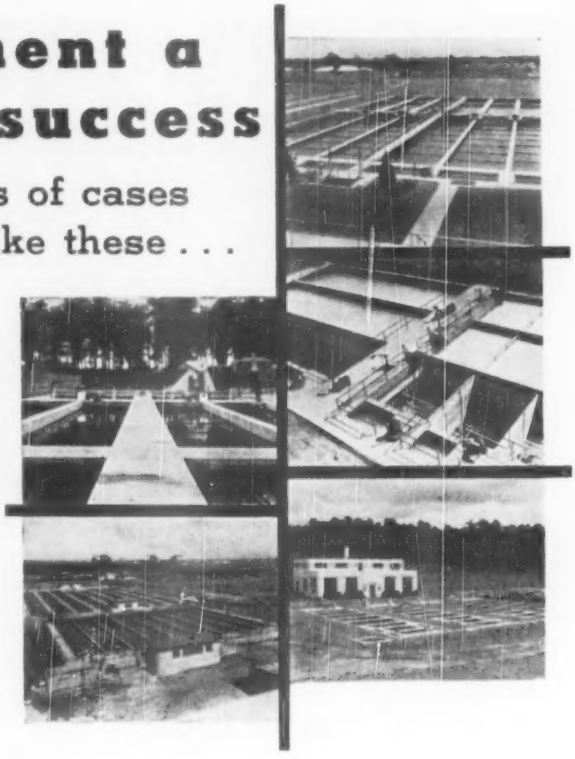

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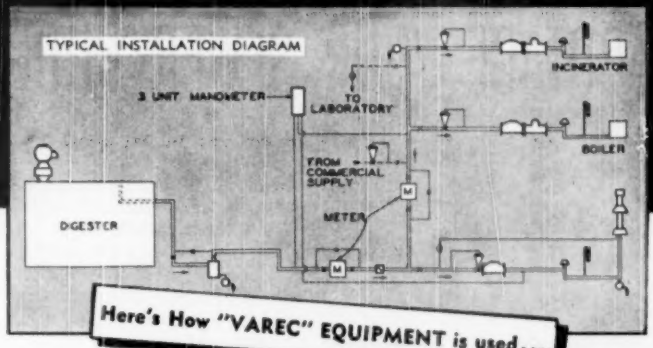


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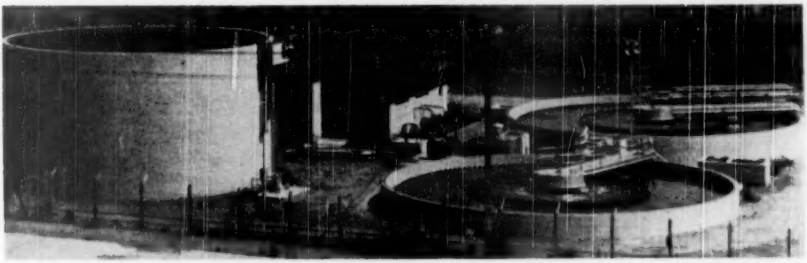

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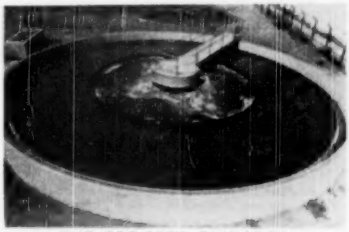

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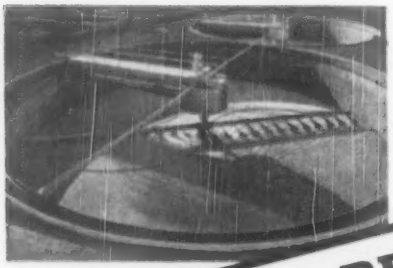

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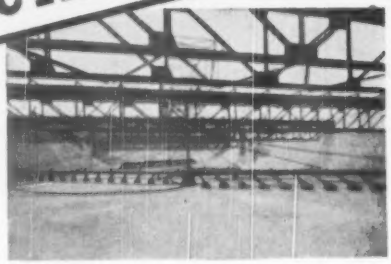

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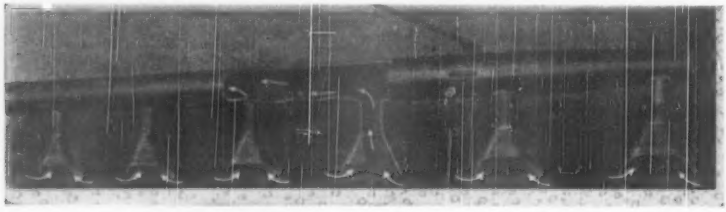

*Arrows indicate direction of sludge removal from tank bottom with Rex Tow-Bro.*

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# SEWAGE AND INDUSTRIAL WASTES

*The Journal of the Federation of Sewage Works Associations*

Volume 22 | JANUARY, 1950 | Number 1

## Contents

**Sewage Works**

Factors Affecting Sludge Force Mains. By JOHN R. WOLFS ..... 1
Sanitary Engineering in a Changing World. By GORDON M. FAIR ..... 11
High-Rate Filtration at Liberty, N. Y. By OLNEY BORDEN, JOHN LAWRENCE, HARRY EICHENAUER AND W. A. HARDENBERGH ..... 17
Discussion by WALLACE W. SANDERSON ..... 24
Primary Standards for B.O.D. Work. By CLAIR N. SAWYER, PETER CALLEJAB, MARVALICE MOORE AND ALBERT Q. Y. TOM ..... 26
Experience with Modified Methods for B.O.D. By F. W. MOHLMAN, E. HURWITZ, G. R. BARNETT AND HARRY KRAMER ..... 31
Disposal of Sewage Effluent at Madison, Wis. By H. O. LORD ..... 41
Control of Bacterial Numbers in Chlorinated Sewage Effluents. By ROLF ELIASSEN AND HERMAN L. KRIEGER ..... 47
Septic Tanks: Design and Performance. By HARVEY F. LUDWIG ..... 55

**Industrial Wastes**

Biological Treatment of Spent Liquor from the Sulfite Pulping Process. By J. M. HOLDERBY AND AVERILL J. WILEY ..... 61
Industrial Waste Lagoons. By WILLIAM A. RYAN ..... 71
Discussion by GLENN SEARLS ..... 75
Characteristics and Treatment of Wool Dyeing Wastes. By J. A. MCCARTHY ..... 77
Biological Oxidation of Industrial Wastes. By H. HEUKELEKIAN ..... 87
Digestion of Combined Tannery and Sewage Sludge. By MORRELL VROOMAN AND VIRGIL EHLE ..... 94
Discussion by W. R. SMITH ..... 101

**The Operator's Corner**

Don't Oversell Sludge ..... 103
Sludge Digestion Tank Heating and Related Problems—A Panel Discussion. By G. E. SYMONS ..... 104
Sewbazooka for House Connections. By J. R. JACOBS ..... 113
Interesting Extracts from Operation Reports: Rochester, Mich.; Green Bay, Wis. .. 114
Oxygen Absorption by Trickling Filter Spray. By WALTER C. ANDERSON ..... 118
Sewer Cleaning Gadgets. By N. DE HAAS ..... 120
Tips and Quips ..... 121

**Editorial**

What's in a Name? ..... 125

**Proceedings of Member Associations**

Pennsylvania Sewage and Industrial Wastes Association ..... 126
West Virginia Sewage and Industrial Wastes Association ..... 127
Iowa Sewage Works Association ..... 129

**Federation Affairs**

Record Registration at Twenty-Second Annual Meeting ..... 131

**Reviews and Abstracts** ..... 140

W. H. WISELY, *Editor*, 325 Illinois Building, Champaign, Illinois
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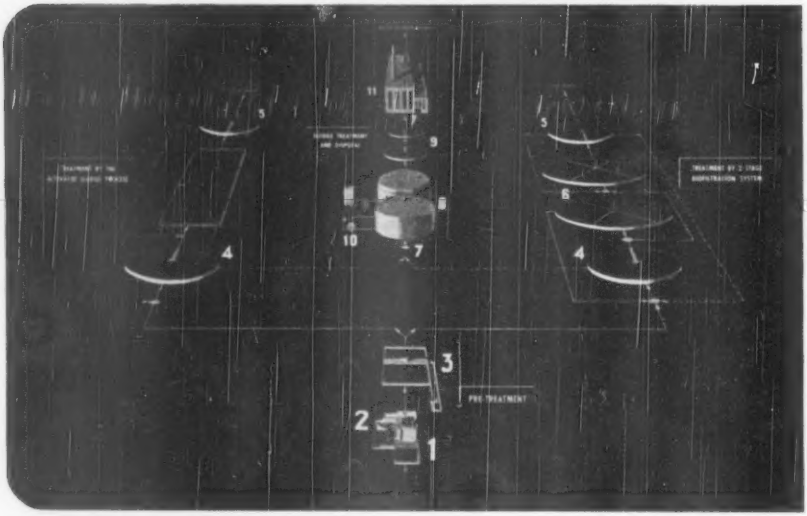

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# Sewage Works

## FACTORS AFFECTING SLUDGE FORCE MAINS [1, 2, 3]

By John R. Wolfs

*Operator, Southerly Sewage Treatment Plant, Cleveland, Ohio*

In an analysis involving the use of operating data, together with the theoretical data available in the literature, it is often difficult to decide which approach to use in a study of this sort. A strictly engineering approach to the subject is on a dollar-wise basis. A strictly theoretical approach makes certain assumptions and predicts the results to be expected. Neither approach would be entirely correct, as the sludge main that the Cleveland Sewage Division has been operating for the past eleven years has not reached the end of its usefulness, but promises many years of service to come. Certain design features that were incorporated in the line have proven themselves in operation. Certain deficiencies have been apparent and have been changed, or will be changed in the next few years.

In spite of the many years of successful operation, it was felt that certain questions should be investigated and a clearer picture of what actually happens in the Cleveland force main formulated. Because the force main itself does not yield well to experimental work, an experimental line was designed to allow measurements to be taken.

The objectives that were desired include the following:

1. The effect of solids content on head loss with various types of sludge.
2. The maximum possible solids content that could be pumped.
3. The effect of thixotropic properties of sludge, due to standing, up to periods of 24 hours.

Not all types of sludges are pumped through the Cleveland main. Only waste activated and primary sludges are pumped. The study included, however, the following sludges:

1. Mixed primary and waste activated sludge from the Easterly plant.
2. Waste activated sludge from the Southerly plant.
3. Digested sludge.
4. Digested sludge chemically conditioned and concentrated.

A search of the literature showed that many investigations of head loss in pipes carrying gravel, sand, pulp, clay slurries, and viscous liquids are recorded.

Certain of these have no counterpart in the sewage field because the specific gravity of the particles normally encountered in sewage is near to that of water, whereas the clays and gravels have a specific gravity of about 2.6. In addition, the above solids are usually of a uniform, finite size. The peculiarities of sewage sludge are well

[1] Abstract of Thesis, Case Institute of Technology, Cleveland, Ohio (1949).

[2] Presented at 23rd Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conference; Cleveland, Ohio; June 22–24, 1949.

[3] Present address: Assistant Engineer, Ohio Dept. of Health, Cleveland, Ohio.

known to sanitary engineers. Experimental work at the University of Illinois by Babbitt and Caldwell involved a variety of solids, including digested sludge, but no primary sludge. Bingham was the first to point out that certain solutions containing solids do not follow the laws of viscous liquids, but act as plastic solids, and he formulated the relationship that exists, using the terms "yield value" and "coefficient of rigidity" to describe the apparent viscosity. Babbitt and Caldwell used this means of checking the results they obtained with digested sludge in calculating the head loss in the Chicago main, and found that the results were well within the expected experimental error when compared to the observed head loss. This method of analysis was followed in the Cleveland experiment so as to check the results and extend the data to the above-mentioned sludges. The runs were made on typical sludges normally encountered. No special preparation was used and all sludges tested were "grab batches" from the various plant sources.

## Test Apparatus

The Cleveland experimental work was carried out on standard weight, 2½-in. galvanized iron pipe arranged as shown in Figure 1. A wooden tank holding 150 gal., measuring 3 ft. by 5 ft. inside and filled to a depth of 2 ft., was used as a sump. The tank was elevated to allow for a bottom connection directly to the pump with a minimum positive suction head of 2 ft. and a maximum of 4 ft. of water. Drain line connections, city water flush, and fill line piping were added as needed.

A 4-in. centrifugal pump, made for sludge pumping, was used as the circulating medium. This pump was equipped with a 6½-in. impeller and was rated at 150 g.p.m. at 40-ft. head. In order to vary the speed, the pump was fitted with a 10-in. V-belt pulley at the coupling and a separate four-speed motor used as an additional drive, the pump having a constant speed motor mounted on the base as part of the regular mounting. The motors then gave speeds of 1750, 1150, 870, 580, and 430 r.p.m.

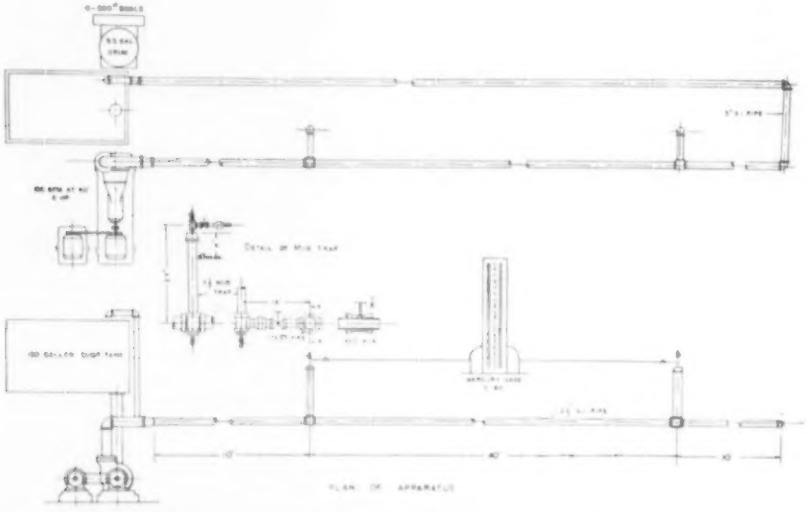

FIGURE 1. General arrangement of force main test apparatus.

A 55-gal. steel barrel, fitted with a drain line, was mounted on a 500-lb. capacity platform balance. By means of a swing pipe, flow could be diverted into this tank, the time being determined with a stop watch accurate to 0.1 sec.

A precision type, mercury differential manometer was used to measure the head loss. The gage was graduated to 0.1 in. corrected to 62° F. Connection was made to the line by means of a specially-designed fitting and mud leg. Both upstream and downstream connections were alike, the gage being placed equidistant from each tap. Flush lines, air vents, and drain cocks were installed as needed.

Standard weight, 2½-in. galvanized iron pipe was tested for head loss. In order to reduce entrance and exit turbulence, the 4-in. discharge from the pump was reduced to 2½ in. by means of a welded fitting having no abrupt size change. An entrance and exit length of 10 ft. was placed before and after the pressure tap. No fittings were used in the test section other than one coupling necessitated by the 40-ft. length of run. The return line and swing connection was of 3-in. galvanized iron pipe, to reduce head loss over the entire run of pipe. The pipe line was level and supported on brackets to prevent sag and misalignment.

## Test Results

The results obtained by running various sludges and determining the head loss at various velocities were plotted as head loss in feet of water per 100 ft. of pipe on the vertical scale and velocity in feet per second on the horizontal scale (Figures 2, 3, 4, and 5). Inasmuch as the relationship between head loss and velocity for water, which is a true viscous liquid, gives a straight line relationship when plotted on log-log paper, the curves show the difference in head loss for sludge, as compared with water, at any given velocity.

In the case of the samples of activated sludge, the solids content is low. The Easterly plant has produced activated sludge of as high as 3.7 per cent solids and the head loss can be expected to be much higher. This will be apparent when the results of other sludges are analyzed.

Other sludges tested consisted of digested sludge chemically conditioned with lime and ferric chloride, as required for vacuum filtration. The samples were drawn from the line leading to the filters and concentrated by standing and decanting until a concentrated sludge was obtained. It was hoped that these sludges would produce a sludge that could not be pumped. Although 7.0 per cent sludge is not unusual when compared to some Imhoff sludges, the fact was at once apparent that the head loss was less than that expected and at high velocities, in particular, the head loss was about the same for all sludges and, surprisingly, about the same as the head loss of water at the same velocity. The percentage of solids is arranged with the highest at the top of the list located to the left of Figures 2, 3, 4, and 5, with the sample number; the volatile content is below the guide line.

The results with digested sludge with no chemicals added showed (Figure 4) that these sludges had more plastic qualities at the lower velocities than the previous sludges. The dotted portions of the curves of necessity were extrapolated because the pump could not produce lower velocities than those shown, and the differences are a little clearer in the lower velocity range. Again, the head loss at high velocities is not too much different from that of water, and practically the same for all sludges. For example, the head loss for water at 7.0 ft. per sec. is 6.8 ft. per 100 ft. of pipe, whereas for sludge it ranges from 7.6 ft. to 9 ft. in 100 ft. of pipe. It is only at the low velocities that the sharp difference is to be found. At 3.0 ft. per sec., water shows

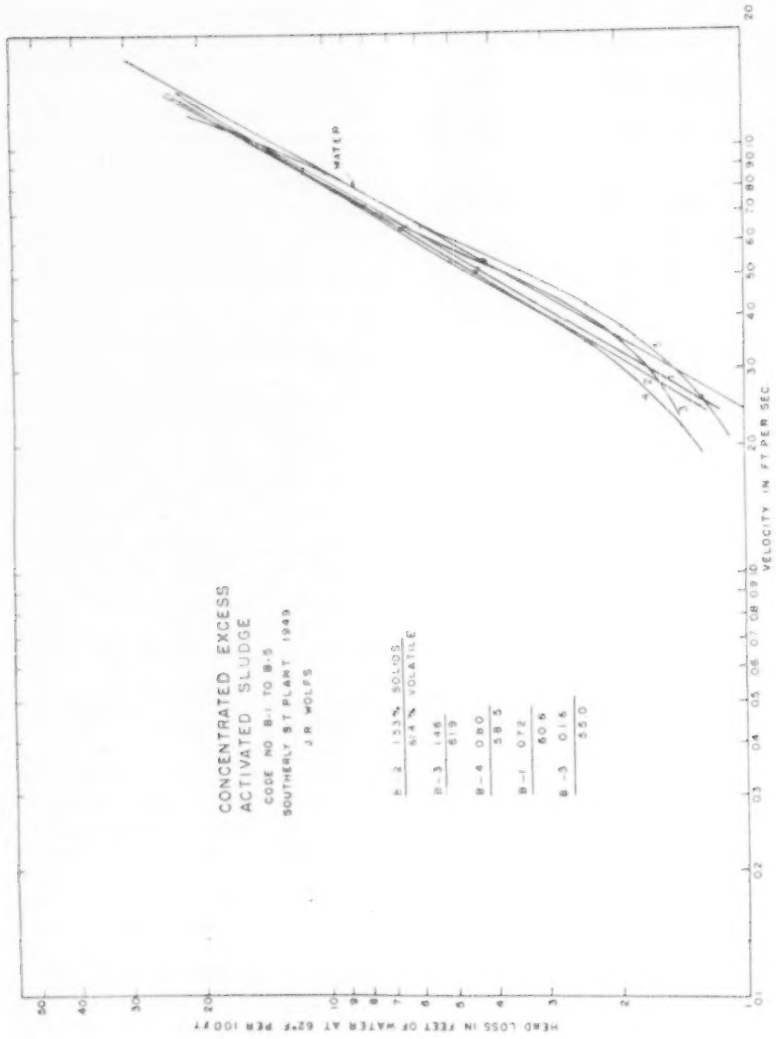
CONCENTRATED EXCESS
ACTIVATED SLUDGE
CODE NO B-1 TO B-5
SOUTHERLY S T PLANT 1949
J R WOLFS
B-2 1.33% SOLIDS
61.4 % VOLATILE
B-3 1.45
61.9
B-4 0.80
59.5
B-1 0.72
60.6
B-5 0.16
55.0
WATER
VELOCITY IN FT PER SEC
HEAD LOSS IN FEET OF WATER AT 62°F PER 100 FT

FIGURE 2.

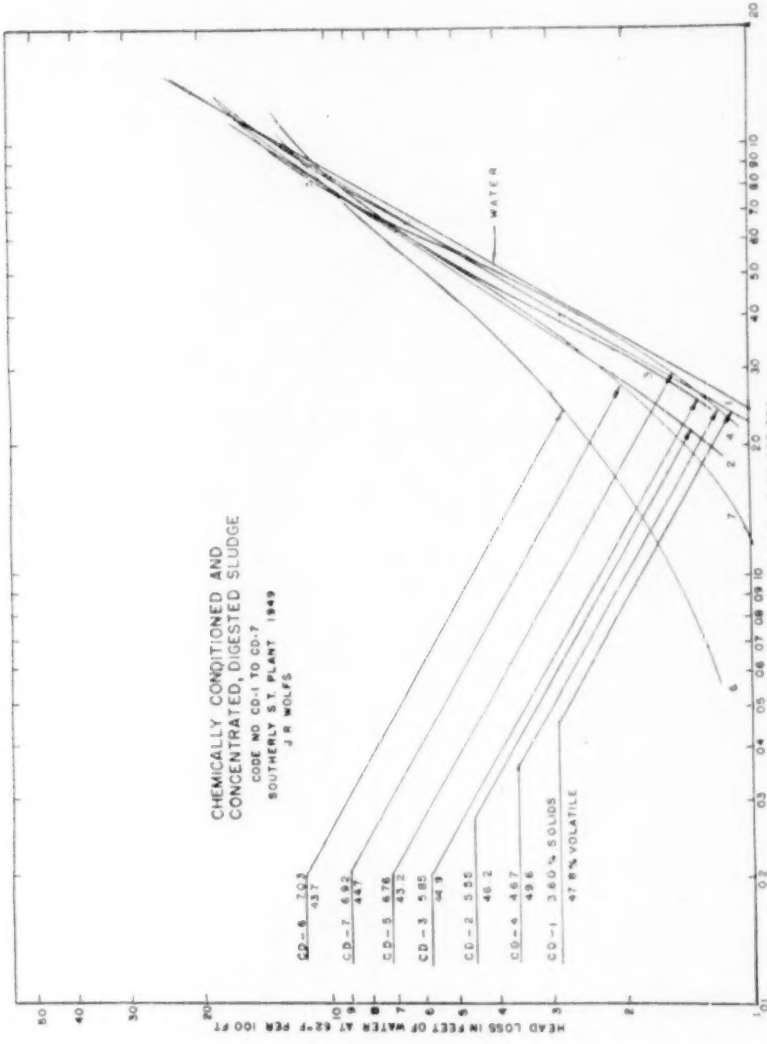
CHEMICALLY CONDITIONED AND
CONCENTRATED, DIGESTED SLUDGE
CODE NO CD-1 TO CD-7
SOUTHERLY S.T. PLANT 1949
J.R. WOLFS
CD-6 7.03 437
CD-7 6.92 447
CD-5 6.76 43.2
CD-3 5.85 44.9
CD-2 5.55 46.2
CD-4 4.67 49.6
CD-1 3.60 % SOLIDS
47.8 % VOLATILE
WATER
HEAD LOSS IN FEET OF WATER AT 62°F PER 100 FT
VELOCITY IN FT PER SEC

FIGURE 3.

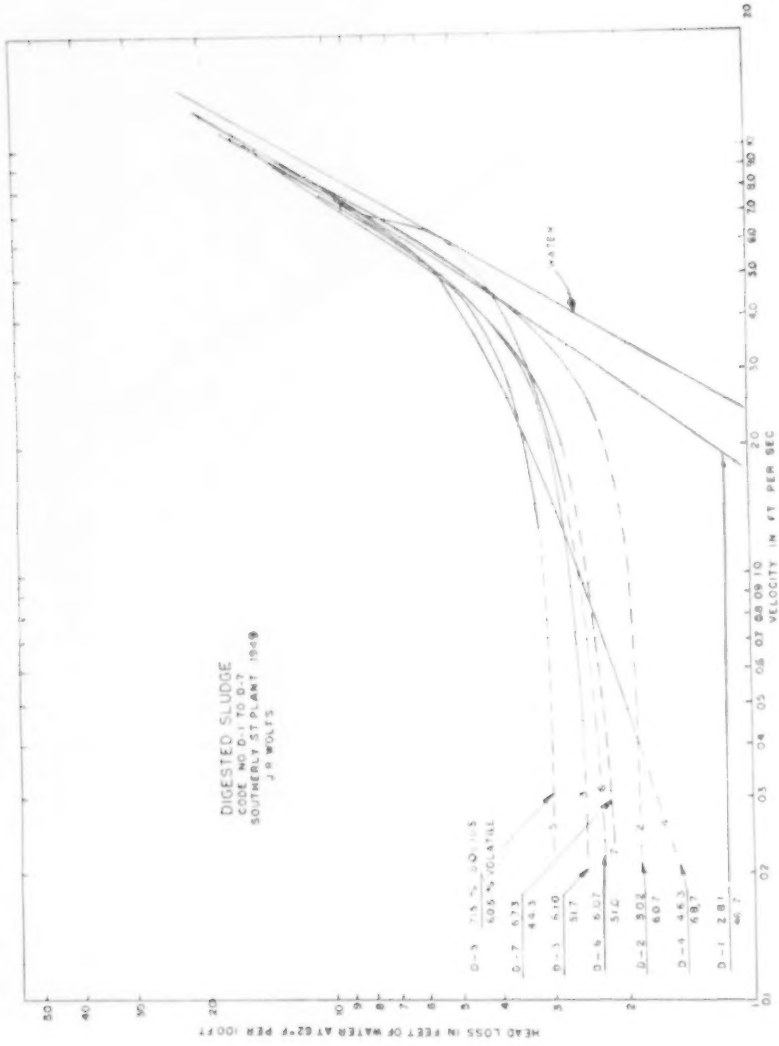
DIGESTED SLUDGE
CODE NO D-1 TO D-7
SOUTHERLY ST PLANT 1949
J.R. WOLFE
WATER
HEAD LOSS IN FEET OF WATER AT 62°F PER 100 FT
VELOCITY IN FT PER SEC
D-3 75% 60 HRS
50% VOLATILE
D-7 6.75
44.3
D-5 6.10
51.7
D-6 6.07
51.0
D-2 9.04
60.7
D-4 4.53
58.7
D-1 2.81
46.7

FIGURE 4.

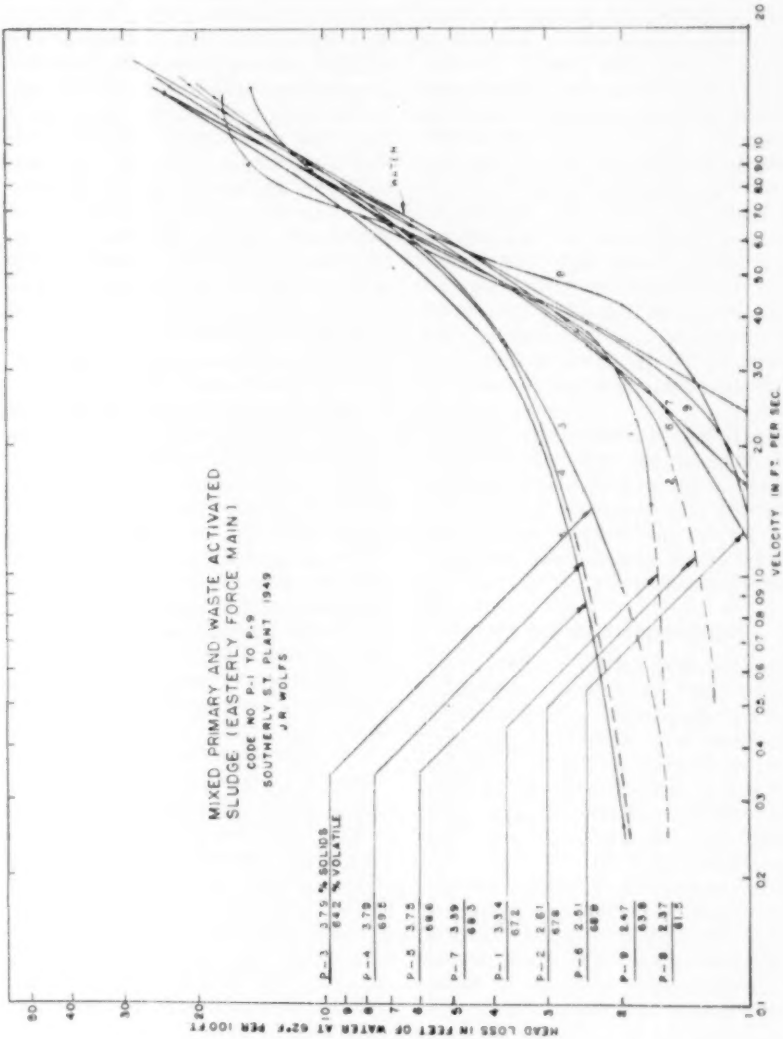
MIXED PRIMARY AND WASTE ACTIVATED
SLUDGE (EASTERLY FORCE MAIN)
CODE NO P-1 TO P-9
SOUTHERLY ST. PLANT 1949
JR WOLPS
P-3 3.75 % SOLIDS
64.2 % VOLATILE
P-4 3.79
69.8
P-5 3.75
68.6
P-7 3.59
68.3
P-1 3.34
67.2
P-2 2.61
67.6
P-6 2.51
68.8
P-9 2.47
63.8
P-8 2.37
61.5
HEAD LOSS IN FEET OF WATER AT 62°F PER 100 FT
VELOCITY IN FT. PER SEC.

FIGURE 5.

1.5 ft. per 100 ft. of pipe and the sludges range from 2.25 to 4.0 ft. per 100 ft. of pipe.

To anyone familiar with primary sludge mixtures, no apology is necessary when the results do not follow smooth curves. The results obtained were plotted as shown in Figure 5, and the few exceptions to the previous results can be explained. The departure from the previous pattern of head loss at the high velocities in the two cases were probably caused by clogging of the joints and elbows, which produced the results shown. The one sludge which has a lower head loss than that of water may be explained, in part, by the difference in temperature, but equally as well by the presence of gas, which can upset the expected head loss greatly.

The factor of major interest is the high head loss at the lower velocities and the great range of head loss with a difference of solids content of 1.5 per cent. Again, the range of head loss is small at high velocities and not much greater than that of water.

## Interpretation of Results

By comparing certain features of the sludges tested, as all were tested under identical conditions, it is possible to make some generalizations which have been known more or less from experience and from the literature, but from such widely different sources, and under such variable conditions, that correlation is difficult.

First, a study of thixotropic properties by means of a Stormer viscometer showed that only at very low velocities could thixotrophy add to the head loss. This tendency of the sludge to jell in open channels and tanks was not experienced in the pipe at low velocities; hence, it is believed that none except unusually thick sludges would ever jell so that a pump could not move them. Other factors (such as air binding or clogging) might enter into the picture, but good operational practice could eliminate this by leaving the line filled with thin sludge which does not show any signs of thixotrophy.

Second, a comparison of solids contents of the various sludges shows at once that at the lower velocities the digested and conditioned sludges show a much lower head loss than the primary sludge, the solids content being made the same. This is in line with the statement of Townend that partially digested sludge was much easier to pump than primary sludge in the Manchester (England) sewage works. By pumping the entire contents of the primary-stage digestion tanks, which includes both digested sludge and supernatant at a solids content of 3 to 4 per cent, at the Mogden (England) works, Townend states that in 12 years of operation little loss of friction has resulted and the grit to a large degree is kept out of the pumps.

Third, the factor of solids content and the maximum that can be pumped was not determined. The experiment failed to produce such a value and another approach is necessary. The fact is that as long as sufficient velocity is available, the sludges can be pumped. The probable limit is around 12 per cent solids, as a sludge of 20 per cent solids can be moved best with a pitch fork.

## Cleveland Force Main

In view of the location of one of the longest sludge force mains—71,000 ft. of 12-in. cast iron pipe—in Cleveland, some mention should be made of it in a paper on force mains. To those not familiar with the Cleveland plants, the Easterly plant, located on Lake Erie, is in a high-class residential area. No rail connection is possible, and any all-year water source is ruled out. The plant must send the entire volume of primary and waste activated sludges produced to the Southerly plant for final disposal within a period of 72 hr., or be totally ineffective to treat the 100 m.g.d. received. It was no small matter to decide to pump the sludge

through a single force main for this distance, and especially a main that has a plan and profile that looks like a railroad line in a logging camp.

To be sure, certain conservative steps were taken to insure satisfactory operation. The solids content was to be 2.0 per cent and capacity was provided for 1.5 m.g.d. This was to be concentrated to 3.0 per cent solids at Southerly, and when no sludge was available sewage was to be pumped, keeping the line flushed. Experience and the necessity of increasing the solids content to relieve overloaded (and still overloaded) digesters at the Southerly plant made it mandatory to increase the solids content. The concentration tanks were found to be of no help in further concentrating this sludge and at present they act only to hold the sludge while it is being charged to the digesters. Planned changes will make it possible to charge directly into the digesters from the force main, with the concentration tanks acting as surge tanks.

Flushing the main carrying the higher solids content sludge did not remove the solids and grease that would accumulate. A contract was let for cleaning the line after 3 years' operation, at a cost of $5,000, plus labor. Repeated cleaning under contract required a week's shut-down period and extra administrative headaches. Borrowing a procedure used by the many oil companies in cleaning their transmission lines, the necessary junction chambers * were constructed for inserting the cleaner at the Easterly plant and removing it at the Southerly plant.

## Cleaning Procedure

The line is flushed with sewage, which takes about 8 hr. as the line holds about 400,000 gal. The air cocks, which are manually operated, are opened and the gas is bled off. The drain cocks allow removal of a large amount of fine grit before putting the cleaner through the line. The cleaner is inserted and forced through the line with the line pressure, which can be raised to 225 p.s.i. if necessary. The progress is checked by pressure readings at the gas vents and when past the last gas vent, the valves are arranged to divert the cleaner into the exit chamber. The cost is about $75.00, with much less loss of time, and usually not more than 48 hr. of sludge is detained. Occasionally, the cleaner has stuck and excessive pressure has burst the line. This is the fault of not cleaning often enough and does not warrant any change other than in operation. It is of interest that the cleaner travels faster than sludge, as a rule. Sludge pumpage is at a velocity of 1.0 ft. per sec., whereas the cleaner travels 2.0 ft. or more per sec.

Normal operation has produced an average value of 168.2 p.s.i. before cleaning, of which 75 p.s.i. is static head. After cleaning, the average pressure drops to 148.3 p.s.i., of which 75 p.s.i. is static head. Hence, cleaning produces 20 p.s.i. reduction in pressure.

The present practice of cleaning the line frequently will allow sludge of higher solids content to be pumped, with no loss of efficiency, and as the cost is low, the cost of cleaning will be reimbursed by power savings.

The sludge has averaged, on a yearly basis, from 3.0 to 3.5 per cent solids for the past few years. Occasional high solids sludges have caused the pumps to be overloaded, necessitating the pumping sewage to lower the head loss. Experience has shown that 175 p.s.i. produced the lowest pump maintenance costs. However, redesign of the pumps and larger motors are indicated. This will, when reduced to a dollar basis, result in a savings, although not from a power standpoint. The need to pump sludges of higher solids content will reduce the excessive amounts of sludge charged into the digesters and removed as partially di-

* See THIS JOURNAL, May, 1948, pp. 572–3.

gested supernatant. The thin sludges handicap the successful operation of the digesters. The thin digested sludges that result produce poor sludges for the filters, which demand high chemical dosages. Maintenance on the filters is excessive because of chemical blinding of the cloths, screens, pipes, and pumps. Indirect maintenance and direct chemical costs are a natural product.

Some questions remain unanswered. The effect of grit is an unknown quantity, but Southerly plant operations prove that tons of grit are pumped into the digesters along with the sludge, in spite of the Easterly grit chambers. Gas at blow-off points, and grit and gas at the low points, are bled off before cleaning only. Because the gas must accumulate in pockets in the line during shut-down, but has never discharged from the line in surges, this may account for the ease with which it is possible to start the 100-h.p. induction motors with no unusual starting equipment. The line reaches full flow in 10 min. The gas may act as a cushion and the effort needed to start 400,000 gal. in motion is less than one would reason.

## Summary

In summary, the study has resulted in additional data and some values from which calculations can be used to check operation of the Cleveland force main. Some new problems have presented themselves and a more sensitive means of determining head loss in the 12-in. main is being studied. As the only real limiations to the pressures that can be developed are those imposed by the line itself, any sludge that can be pumped within this limit should be so pumped as to save the necessity of charging the now overloaded Southerly digesters with additional water. This will necessitate a more powerful, durable pump, past experience having shown what should be avoided. It is hoped that this will reduce the present limitation on the sludge now pumped.

## Acknowledgments

Grateful acknowledgment is extended to J. W. Ellms, commissioner of sewage disposal, for his original interest in this project; and to J. J. Wirts, formerly superintendent of the Easterly sewage disposal plant, for permission to use data from an article published in *Water and Sewage Works*. Also to G. E. Flower, superintendent of Southerly sewage plant, and Walter E. Gerdel, superintendent of the Easterly sewage plant, as well as to numerous fellow-workers, for their interest and help.

# SANITARY ENGINEERING IN A CHANGING WORLD*

By Gordon M. Fair

*Abbott and James Lawrence Professor of Engineering and Gordon McKay Professor of Sanitary Engineering, Harvard University, Cambridge, Mass.*

Had you visited Boston a century ago, instead of in A.D. 1949, you might have encountered on the steeps of Beacon Hill a middle-aged gentleman, a sheaf of papers or documents under his arm, walking rapidly and full of purpose from the library in the rotunda of the State House to the Registry Department of the City of Boston on School Street. Or mayhap this person would be taking a shortcut from Tremont Street through the Old Granary Burying Ground to the rooms of the New England Historical and Genealogical Society, of which he was an enthusiastic and honored member.

This man, if he really was the person I have in mind, would have been greeted by contemporary Bostonians as the bookseller Lemuel Shattuck. At the time of your encounter, furthermore, he would be one—and, more is the pity, the only dutiful one—of three commissioners appointed by the Governor, with the advice and consent of the Council, as authorized by a resolve of the Legislature "to prepare and report, to the next General Court, a plan for a Sanitary Survey of the State, embracing a statement of such facts and suggestions as they may think proper to illustrate the subject."

According to the custom of the times Mr. Shattuck would be dressed in a dark suit of English worsted, his strong and thoughtful face, not without humor, rising above a high collar and black cravat, his hair receding from a wide forehead which made a fit companion for a large nose and a pair of deep-set eyes below dark and bushy eyebrows.

Mr. Shattuck might well be in a hurry, for he was to complete in less than a year, almost unaided and with the expenditure of but $500, his prophetic "Report of a General Plan for the Promotion of Public and Personal Health." This report, as we shall see, was to become of paramount importance to the development of sanitary engineering, in spite of the fact that, in the words of Dr. Henry I. Bowditch, the report "fell stillborn from the hands of the State printer." For many years most of its 2,000 copies were permitted to gather dust in the attic of the State House. Nevertheless, the report was eventually brought back to light and became the source of inspiration for the formation, in 1869, of the Massachusetts State Board of Health, the first board of its kind in this country.

## Recommendations Still Valid

The substance of the report was contained in fifty recommendations, many of which were incorporated in the aims and objectives of the State Board of Health. However, the report was more ambitious than this in its ultimate goals, and Winslow (1) has declared that thirty-six of the recommendations are now "universally accepted practice"; that but four are "unimportant or, in some degree, unsound"; and that ten, although "as sound as the thirty-six proposals which have been generally accepted," were sufficiently advanced in their objectives that "their

* Address presented at Annual Luncheon, Twenty-second Annual Meeting, Federation of Sewage Works Associations; Boston, Mass.; October 17–20, 1949.

importance has as yet not been fully realized."

Among the half hundred measures that Shattuck proposed for the advancement of the public health of the Commonwealth was the creation of a general board of health, composed so far as practicable "of two physicians, one counsellor-at-law, one chemist or natural philosopher, one civil engineer, and two persons of other professions or occupations; all properly qualified for the office by their talents, their education, their experience, and their wisdom." The Board was not to be selected exclusively from one profession because Shattuck anticipated that numerous questions, requiring a knowledge possessed by different professions, would be presented for discussion and decision, and that it would be desirable that the Board should bring competent knowledge to the investigation of every subject. According to Shattuck, "the idea which too generally prevails, that everything relating to health belongs exclusively to one profession, operates against sanitary improvement." The "one profession" that Shattuck had in mind was the medical profession. In the course of time, Shattuck's prophetic recommendations prevailed, and chemists, engineers, and lawyers cooperated with medical men to cultivate the ever-widening fields of public health.

According to Shattuck, the civil-engineer member of the Board was to possess "competent knowledge to determine the best methods of planning and constructing public works, and the best architectural sanitary arrangements of public buildings, work shops, and private dwellings," while the chemist or natural philosopher would answer and make special investigations concerned with the "many questions relating to the influence of the elements on the production or prevention of disease." It is to these suggestions, therefore, that we may trace the genesis of the sanitary engineer, the sanitary chemist and biologist, and the industrial hygiene engineer.

Nineteen years were to elapse before the Massachusetts State Board of Health was organized in the pattern suggested by Lemuel Shattuck, and five more before the Board included an engineer member, John C. Hoadley. The Board, however, employed as consultants some of the outstanding civil engineers of the time, in particular James P. Kirkwood, who was the first American engineer to build a water filtration plant (Poughkeepsie, N. Y.), and E. S. Chesbrough, who was to become celebrated for his designs of some of the great sewer systems in the United States (for example, Boston and Chicago). Investigations that involved problems of chemistry were generally assigned to Professor William R. Nichols, of the Massachusetts Institute of Technology, who thereby became the pioneer American water chemist.

## Beginnings of Stream Pollution Legislation

Not until 1886, however, did the Board include an engineering department staffed with full-time personnel. In that year the Board was reorganized under the chairmanship of Dr. Henry P. Walcott. In that year, furthermore, Hiram F. Mills, chief engineer of the Essex Company, which owned the dam and canal on the Merrimack River at Lawrence and controlled the water needs of the mills, became the engineer member of the Board. In that year, finally, the Legislature of Massachusetts saw fit to pass "An Act to Protect the Purity of Inland Waters" and to provide funds for the development of an engineering staff and for the systematic analysis of water in order to carry out the provisions of the act. F. P. Stearns became the chief engineer of the engineering department and X. H. Goodnough the assistant engineer. For ten years the analytical work of the department was done in

the laboratories of the Massachusetts Institute of Technology and there brought a notable group of chemists and biologists into contact with the problems of sanitary engineering.

Subsequent developments are reported by the writer in another place (2) substantially as follows:

In order to conduct experiments to determine the best practicable methods of purification of sewage or disposal of manufacturing refuse, Mills placed at the disposal of the State Board of Health his own laboratory at Lawrence in which, with the aid of John R. Freeman, he had begun to conduct promising hydraulic investigations. This laboratory was renamed the Lawrence Experiment Station and has continued its useful existence ever since. As a laboratory for sanitary research, this station was the first of its kind, and its influence on the progress of sanitary engineering cannot be overestimated. To staff the station, Mills drew heavily on young graduates of the Massachusetts Institute of Technology who had come under the influence of teachers who were then active in the chemical and biologic investigations of the State Board of Health.

Thereby was initiated a decade of sanitary investigation, the like of which has never been seen again. With the support of Dr. Walcott, and unified in their objectives by Mills' broad conception of what was needed in the task ahead, the Engineering Department, the Water Laboratory, and the Experiment Station collaborated with imagination and zeal to initiate great engineering enterprises, lay the foundation for sanitary analysis, and establish the experimental method as a means for determining the scientific and economic basis of public sanitation. The association of young men in this great adventure in sanitation appears to have been mutually so inspiring that there was to be hardly a man among them who did not make a significant contribution to the advancement of knowledge during his stay with the Board and who did not, as well, make a name for himself in later life.

A list of these men would include, among others, the names of Thomas M. Drown, chemist, successor to Professor William R. Nichols at the Massachusetts Institute of Technology and later president of Lehigh University; William T. Sedgwick, biologist, later professor of biology at the Massachusetts Institute of Technology; Allen Hazen, engineer investigator, later one of America's great practitioners; George W. Fuller, chemist, who at Louisville, Kentucky, laid the foundation for rapid sand filtration; Gary N. Calkins, biologist, later professor of protozoology at Columbia University; Edwin O. Jordan, bacteriologist, later professor of bacteriology at the University of Chicago; and Harry W. Clark, chemist, later director of the Water Laboratory and the Lawrence Experiment Station.

Notable among the great engineering enterprises of the group were the investigations that produced the Metropolitan Sewerage System of Boston, the Metropolitan Water Supply of Boston, and the Charles River Basin —public works that satisfied the highest standards of engineering achievement and that continue to serve their intended function with success and distinction.

Many of the early studies of water purification and sewage treatment at the Lawrence Experiment Station are counted among the classics of sanitary engineering literature. Some of them were so fundamental and so well conceived that they have continued to be reprinted in books on sanitary engineering for half a century. The Lawrence Experiment Station eventually became a mecca for engineers, chemists, and biologists interested in the purification of water, the treatment of sewage and industrial wastes, and the control of stream pollution. Most of the important American laboratories for sanitary research, whether supported

FIGURE 1.—Early photo of Lawrence Experiment Station.

by federal, state, municipal, or university authorities, are linked in one way or another to Lawrence and to the men who moved from Lawrence into engineering practice.

I have told the story of Lemuel Shattuck and the Massachusetts State Board of Health not as an exercise in antiquarianism, but for the more cogent reason that, the future being heir to the past, a study of the past may help us to plan intelligently for the future.

## Many Advances in Past Century

In terms of the past, we have arrived at the end of a century during which sanitary engineers and their associates in chemistry and biology have contributed greatly to the advancement of public health. To do so they have aligned themselves with the aims, purposes, and administrative structure of public health departments. Their association with these departments has fitted them for a number of important tasks. They have been able to interpret the requirements of public health to their fellow engineers in private and public practice; they have been called upon to advise communities and private citizens about sanitary measures and needs; they have given voice, in the halls of legislatures, to the sanitary engineering requirements of municipalities and rural areas; they have exercised such measure of police power as has been needed to enforce sanitary regulations; they have aroused public interest in sanitary progress; they have supervised the operation of existing sanitary works; they have conducted research that has advanced the art and science of sanitary engineering; they have taken control of sanitary works in order to suppress waterborne epidemics; and they have mobilized in time of disaster to coordinate the management of emergency sanitation. Under their stimulus, about 70 per cent of the urban communities of this country have been provided with water supply systems. Some 14,000 in number, these systems now serve approximately 85,000,000 people. Almost as great a population (70,000,000) has been connected to public sewerage systems, and 70 per cent of these people discharge their sewered wastes to

5,500 sewage treatment plants. In terms of the vital bookkeeping which measures public health accomplishment, the death rate from typhoid fever has dropped, during the last half of this first century of public health, from about 30 per 100,000 population per annum to less than 0.5. In comparison with the year 1900, therefore, almost half a million persons annually are spared the agonies of an attack of typhoid fever and 50,000 are preserved from premature death due to this cause. The story for the other enteric infections that can be controlled by sanitary effort is much the same. By these dramatic successes the public health yardstick of sanitation, which is calibrated in terms of the prevalence of the enteric diseases, has been shrunk to micrometric dimensions; typhoid fever and the dysenteries have become asymptotic to the time and effort axis; and the sanitary engineer would seem to be slated for the position of low man on the totem pole of public health.

## Large Challenges in Next Century

As we approach the second century of public health in America, therefore, we must answer an important question, which is in the minds of many public health administrators and which can be formulated as follows: Has the sanitary engineer, as a dynamic force in public health, arrived at the Nirvana towards which all good servants of public health must strive? Expressed in other words, have sanitary engineers by annihilating all but traces of the enteric diseases from the annual reports of causes of death in the United States destroyed the necessity for their continuing association with public health authorities? The answer, in my opinion, is an unqualified "No."

Let those engineers and administrators, who feel that the emphasis of sanitary engineering in public health departments should be shifted from water supply in all of its engineering implications to subjects of the order of engineering challenge of restaurant sanitation, be confronted by some of the following information. There are in this country still 6,000 communities that stand in need of a public water supply, and more than 9,000 communities that lack sewerage systems. In our rural areas, some 33,000,000 people do not possess facilities for excreta disposal of even the most elementary kind. Some of the largest cities in the land are supplied with water that receives no treatment other than chlorination. Other large communities draw their supply from bodies of water that they themselves or their neighbors debase to an extent such that the water delivered to the community can in some instances be described only as a modified sewage or trade waste. Many of our older municipalities are burdened with an inheritance of combined sewers and the palliative of intercepting systems. As a result, the recreational areas that lie at their doorsteps are fouled by storm-water overflows and cannot perform freely the health-promoting function for which they should be intended. A national stream-pollution control act has only just been passed, and the nation is girding its loins for a concerted, country-wide attack on the problem of the degradation of its water resources by industrial wastes as well as domestic sewage. Wastes from organic synthesis, production of antibiotics, and the utilization of atomic energy present new and startling demands on our water resources. The growth of certain areas of the country that boast of most of its sunshine is being stunted by inadequacy of water supply. Our knowledge of the fundamental principles of water purification and sewage treatment remains lacunal, while the discovery of new public health hazards —infectious hepatitis, dental fluorosis, and methemoglobinemia, to mention but a few of recent vintage—imposes on us the need for a continuing aware-

ness of human ecology in its relation to water.

Those young men in sanitary engineering for whom "Macedonia is too small" will find a Shattuckian opportunity in other, vast areas of the world. Theirs to emulate are the accomplishments of engineers allied to the Rockefeller Foundation, the Institute of Inter-American Affairs, and more recently the World Health Organization. Sanitary engineering, as someone has said, is America's gift to the world. I am certain that Point 4 of Mr. Truman's "bold new program" will succeed only if it is realized that sanitation of the backward areas of this globe is a *sine qua non* to the success of their economic development. A bold new program will have as its goal not merely the checking of killing and debilitating diseases, but also the eradication of their causes or causative organisms. The eradication of *Anopheles gambiae* from Northeastern Brazil and the probable eradication of *Anopheles labranchiae* from Sardinia, which is now in progress, are cases in point. We have kept cholera from our shores for many decades; but why should the cholera vibrio be permitted to survive as a menace to a world in which speed of modern transportation has destroyed the time barrier to the renewed dissemination of this scourge? Why should intestinal parasites of many kinds be allowed to make of our globe a wormy world?

## Professional Freedom Needed

If we are to accept the challenge that I have sketched, you will agree with me that we shall have to do so with all the freedom and independence of action and judgment that our status as engineers, chemists, or biologists guarantees to us. Whereas we are willing and anxious to continue our close association with the other professions that are now active in public health organizations, we should be unwilling to follow those, in my opinion, short-sighted spokesmen who have set as their goal the welding together of all manner of highly individualistic skills into a self-contained public health profession protected by a ritualistic system of training, occupational advancement, and accreditation. What these persons fail to recognize is that, whatever their motivation may be, they are advocating the erection of barriers not unlike those maintained by some members of the medical profession in the days of Lemuel Shattuck. Today, as then, such barriers operate against sanitary improvement. Today, as then, the promotion of public health is a matter that does not belong exclusively to a single profession but concerns every profession and every person. The strength of the modern public health campaign lies in the unity of its purpose and the diversity of the means for its accomplishment. Let not, therefore, small minds keep us from pursuing the task that lies ahead in the second century that is to come.

"For more is not reserved
To man, with soul just nerved
To act tomorrow what he learns today:
Here work enough to watch
The Master work; and catch
Hints of the proper craft, tricks of the tools true play."

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2. Fair, Gordon M., *New England Jour. of Medicine*, **232**, 443 (1945).

# HIGH-RATE FILTRATION AT LIBERTY, N. Y.*

By Olney Borden, John Lawrence, Harry Eichenauer, and W. A. Hardenbergh

*Respectively, Consulting Engineer, Superintendent of Public Works, and Operator, Sewage Treatment Plant, Liberty, N. Y.; and Editor, Public Works Magazine, New York, N. Y.*

Liberty's high-rate filter plant resulted from the same conditions that now confront many other communities—a primary treatment plant built in 1931 was no longer able to prevent serious stream pollution conditions. The village, a popular summer resort, was growing; a milk plant, two laundries, and a slaughterhouse contributed considerable organic loading to the sewers; and this loading was heaviest in the summer when stream flow was smallest. In fact, during summer dry-weather periods the sewage flow was often greater than the flow in the stream into which it was discharged. In 1939, it was decided to add secondary treatment facilities.

In searching for a satisfactory method of treatment, the following general rules for guidance were laid down: (1) The effluent had to be good enough so that the stream into which it was discharged would show no visible evidence of pollution at any time; (2) the plant had to be flexible enough to handle not only the very heavy summer week-end populations, but also the slugs of waste from the milk plant and the laundries; (3) the method adopted had to be suitable and economical for handling the lighter winter loads; and (4) it was desirable that the plant be operable by one man, for the cost of 24-hr. operation can be a heavy burden on a small community.

Consideration was given to various methods of treatment. Standard trickling filters alone would not give the desired degree of treatment, and 2 acres of sand beds would be required for final treatment. Also, sand beds would have necessitated repumping of the sewage, and open beds were undesirable in such close proximity to the built-up sections near the plant. Activated sludge was discounted, in part because of the sudden very heavy increments of industrial wastes, and in part because the State Department of Health required 24-hr. or 3-shift operation for such a plant. High-rate, two-stage filtration was finally selected. The secondary units of the plant are shown in Figure 1.

This was a rather daring decision because there was, at the time, no plant of this type in the East; and, in fact, only a relatively few installations had been made anywhere. Although the principles of high-rate filter loading had been quite well established, many minor factors of design were fluid and had to be worked out to meet the conditions at Liberty.

## Design Bases

The plant was designed for a flow of 1.1 m.g.d. of sewage with a B.O.D. strength of 425 p.p.m. On the basis of raw sewage strength, the filter was designed for a loading of 3.1 lb. per cu. yd. of stone, or 5,000 lb. per acre-ft. With 35 per cent removal in the primary tanks, the actual loading for 1.1 m.g.d. is slightly over 2 lb. of B.O.D. per cu. yd., or 3,250 lb. per acre-ft. The 3-ft. stone depth of the two 85

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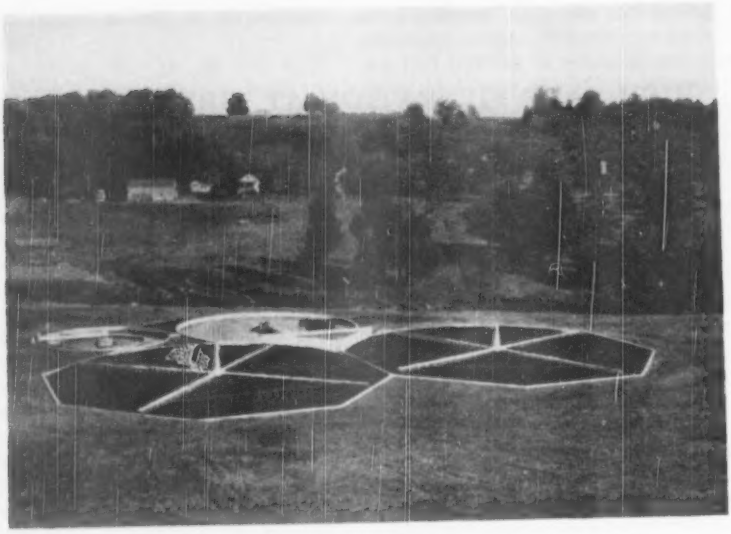

FIGURE 1.

ft. diameter filters was determined, in part, by the topography of the plant site; deeper filters would have required repumping during periods of high water in the stream.

The plant employed two new principles. One was that the amount of recirculation was held constant and was always uniform, whereas in previous plants of this type the ratio of recirculation to the flow of raw sewage was held constant. The advantage of the constant recirculation method was that it avoided starting and stopping of the recirculation pumps and permitted them to operate continuously—even throughout the year—at their designed heads and speeds, thus obtaining maximum efficiency. Only low-water and high-water cutoffs, operating in case of a pipe break or a flood and requiring manual restarting, were provided. The uniform recirculation gives better efficiency in B.O.D. reduction in dry-weather periods, when both sewage flow and stream flow are low.

A second unusual factor was the decision to design the plant so that in winter the two filters could be used in parallel as low-rate filters without recirculation. It was realized that the unit loading on the filters would be high as compared to usual low-rate filter loadings, even though winter flows are much smaller and B.O.D. concentration much less. Actually, during winter operation, the loading is about 1,000 lb. of B.O.D. per acre-ft., about twice normal low-rate filter loadings. However, it was believed that a sufficiently good effluent would be produced to prevent nuisance, and this has proved to be the case. In addition, the design of the plant permits the use of any one of several modifications in operation. For instance, it is possible to recirculate to the primary settling tank and operate the filters in parallel; or to operate the primary filter as a low-rate filter and recirculate to the secondary filter. Thus, almost any desired degree of treatment is obtainable.

Appreciating that, by the standards of 1940, the loading on the filters was very high, special attention was paid to design of the underdrainage and ventilation system. An underdrainage

system was installed having an unusually large opening for ventilation and ample channels for carrying off the maximum flow expected, while also providing space for air currents. Finally, an effluent filter was installed to provide additional treatment, if needed, to the effluent from the secondary settling tank.

## Plant Data

The original rectangular primary settling tanks built in 1931 were designed to provide 3-hr. detention for a flow of 1 m.g.d. Inasmuch as recirculation of 2 m.g.d. was desired for each stage, this meant that, with a flow of 1 m.g.d. of raw sewage, the detention period would not exceed 1 hr. In operation, it has been found that the average B.O.D. removal in the primary tanks with a detention period of 1 hr. is 43 per cent. In winter, with no recirculation and with lower flows, the detention in the primary tank is 3 to 7 hr. and the average B.O.D. removal is 47.6 per cent. The range is from 30 to 62 per cent, being greater for strong sewages.

Both filters are identical except for the size of the stone, the primary filter being of 2½-in. stone; the secondary filter, 1½-in. stone. The flow from the primary settling tank goes to a dosing tank. In summer, with high-rate filter operation, the entire flow is applied to the primary filter. This includes both the original volume of flow and the recirculation of 2 m.g.d. to the primary settling tank. In 1948, flows were often considerably in excess of 1.2 m.g.d. With the 2.0 m.g.d. recirculation, and with a filter area of 5,675 sq. ft., the rate of application was as high as 25 m.g.a.d.

Effluent from the primary filter flows to a small sump, where 2 m.g.d. is picked up by the recirculation pump and returned to the primary settling tank. The excess over 2.0 m.g.d. overflows a weir to a secondary sump, in which a 3-m.g.d. pump operates, delivering to the secondary filter. The difference between the overflow volume from the primary sump—which represents the raw sewage flow and is normally 1.0 to 1.2 m.g.d., but may be more—and the 3-m.g.d. capacity of the pump is drawn from the secondary clarifier. Dosage on the secondary filter is always 3 m.g.d., or at a rate of about 23 m.g.a.d. Effluent from the secondary filter flows to the secondary clarifier, which has a 3-hr. detention period with a flow of 1 m.g.d. Although 3 m.g.d. reaches the secondary settling tank during operation as a bio-filter, 2 m.g.d. are withdrawn for application to the secondary filter, so that a 3-hr. detention period actually is provided.

In winter operation the pumps are shut down, the sumps are drained, and the dosing tank delivers settled sewage to the two filters.

Because the potentialities of two-stage high-rate filters were not fully known at the time the plant was designed, and because it was desired to insure a good effluent, a magnetite filter was installed to take the effluent from the secondary settling tank. This filter, which cost about $15,000 installed, was designed to operate at a rate of 1½ gal. per sq. ft. of filter surface per minute. The magnetite sand was graded to the usual specifications for a rapid sand water filter.

The original plant provided an unheated digester. In 1940, in conjunction with the construction of the high-rate filters, a 35-ft. diameter heated digester was built. The 1931 plant included about 6,500 sq. ft. of glass-covered sludge drying beds. In 1940, a 50-sq. ft. vacuum filter was added, primarily to care for winter conditions. In 1948, a 50-ft. diameter heated digester of the prestressed concrete type was built, and in 1949, a 150-sq. ft. vacuum filter was installed for sludge disposal. Abandonment of the sludge drying beds is contemplated.

There are several other features of

interest in the plant. Flood flows in excess of about 2.0 m.g.d. automatically shut off the recirculation pumps, requiring manual restarting. The secondary settling tank and the magnetite filter are protected against excessive sewage flows by a siphon flood discharge, which has a capacity about equal to the capacity of the incoming sewer.

### Factors in Design

Naturally, observations and experiences in operation have taught things about design that were not known. In the first place, in Liberty, which is a typical summer resort, the ratio of peak hourly flows to average daily flow is rarely more than 140 per cent. It is believed that this ratio will hold for most summer resorts where hours of retiring and rising are, of course, under no restrictions. Second, it is not believed possible to design a digester on an average load basis—as by combining winter and summer populations. Solids disposal facilities must be designed for the maximum 4-week loading; and it is possible that a shorter period than 4 weeks may govern. Observations over a 4-yr. period when digester capacity was inadequate indicate what an important adverse effect on plant operation such conditions can have.

The stone in the secondary filter should not be smaller than the stone in the primary filter. In the Liberty plant, as previously stated, the stone in the primary filter is of 2½-in. size; in the secondary filter, 1½-in. It is believed that 3-in. stone, or possibly larger, would be better in both filters. Good underdrainage and ventilation must be provided, especially in high-rate filters.

In designing the plant, consideration was given to many factors thought to induce better operation. There is not a pipeline in the plant that can freeze; special attention was given to safety factors and to the elimination of heavy labor requirements. A pleasant and attractive office, showers and locker rooms, and an adequate laboratory were provided. All these features have been a first class investment.

As previously intimated, Liberty plans in the future to rely wholly on filters for sludge dewatering. Although the cost of conditioning and filtering sludge is considerable, it is believed that it will be less than the cost of the hand labor and truck time required for removing dried sludge from the beds. Moreover, unfavorable weather, wet or cold, will not interfere with filtration.

### Operational Data and Characteristics

All operation data for the plant are based on samples taken from 8 A.M. to 3 P.M. It is appreciated that results from such sampling schedules may show considerable deviations from results obtained by 24-hr. composite samples, but there is only one operator. The plant is producing a good effluent and the tests are made principally to check plant operation and local conditions of loading over long periods.

About two years ago operating results of the various plant units were analyzed. Average B.O.D. removal by the primary settling tank was 47.6 per cent without recirculation, and 43 per cent with recirculation. When operating as a high-rate filter, removals in the primary filter normally range between 44 and 48 per cent of the applied load, and are higher with heavier loads; for instance, when loadings reach 11 lb. per cu. yd., removal averages 54 per cent. Removals in the secondary filter, with high-rate operation, ranged from 45 to 50 per cent of the applied B.O.D., but were higher with heavier loads; for instance, with a loading of 6 lb. of B.O.D. per cu. yd., the removal was 63 per cent. Removals in the secondary clarifier ranged from 35 to 40 per cent. Removals by the magnetite filter usually exceeded 60 per cent.

Averages of all B.O.D. samples taken during high-filter operation in 1945 were as follows: Raw sewage, 344 p.p.m.; secondary clarifier effluent, 23 p.p.m.; final effluent, 6.7 p.p.m. The highest final effluent B.O.D. reported for the year was 14 p.p.m. In 1946, the average B.O.D. results were: Raw sewage, 367 p.p.m.; secondary clarifier effluent, 27 p.p.m.; final effluent, 9 p.p.m. The highest final effluent B.O.D. reported was 17 p.p.m. Suspended solids in the effluent averaged less than 10 p.p.m. for both years.

Over a 2-yr. period, winter loadings on the filters averaged 0.77 lb. of B.O.D. per cu. yd. Average removal by the primary filter was 0.36 lb., and for the secondary filter, 0.24 lb. Except for stone size, the two filters are identical, and it is believed that application to the two filters is the same, so that organic loading and rate of application should be the same.

In general, a period of 4 to 6 weeks is required after recirculation is started in the spring before normal high-rate filter operating results are obtained. Similar high-rate filter operating characteristics persist for about the same period in the fall after recirculation is discontinued.

*Flow*

The normal dry weather sewage flow at the time the secondary treatment plant was installed in 1940 was 0.4 m.g.d. during the winter months and 0.9 m.g.d. during the summer months. In rainy weather the flow increases to slightly over 3.0 m.g.d. and may stay at that rate for several hours. Average monthly flows for 1948, in million gallons per day, were:

| | | |
|---|---|---|
| Jan. 0.70 | May 0.90 | Sept. 1.00 |
| Feb. 0.70 | June 1.00 | Oct. 0.97 |
| Mar. 0.70 | July 1.10 | Nov. 0.90 |
| Apr. 0.80 | Aug. 1.10 | Dec. 0.90 |

In taking these averages, all unusually high storm flows were neglected and the flows shown are considered a normal sample. It is interesting to note that the average monthly flow does not vary more than 50 per cent from low winter flow to peak flows during the summer resort season. This probably is due to the fact that nearly all buildings in the village are now occupied throughout the year and the summer increase in population is mostly due to hotels and rooming houses. Even in the case of hotels, however, the spread between winter and summer population has decreased considerably in the past few years; for example, the largest hotel, with a maximum summer population of 1,200, now has an average winter population of 600.

*Primary Tanks*

The primary settling tanks have been in continuous operation since their construction in 1931. In order to avoid ice in the primary tanks, the skimmers were run continuously during the winter of 1931–32 and the practice has been continued. Despite continued operation of the skimmers throughout the 18 years since their installation, the electric motors have not had any repairs or replacement and the only mechanical replacement required was new chains in 1948.

The primary tanks have been overloaded by recirculation and by storm flows, but the reduction of B.O.D. and suspended solids has not varied much from 50 per cent whenever tests have been made.

*Stone Filters*

The stone filters were put into operation during the summer of 1940 and have operated with excellent results ever since. A number of interesting operational features were noted during the early years.

Recirculation was shut off during the first winter of operation and on very cold nights the siphon would cut off for short periods. The distributors stopped and the oil in the center piers got cold. Then, when the siphon discharged

again the distributors would not rotate. Ice formed along the arms and on top of the stone, and the operator had a 2-hr. job the next morning cleaning off the ice and starting the distributors.

Also, on very cold, windy nights, the wind stopped the distributor and caused ice to form, with the same troublesome results. In the winter of 1942–43, the primary filter was operated as a low-rate trickling filter and the recirculating pump was operated to keep the secondary filter running also. Under these conditions, all of the ice troubles were remedied.

Both filters start to unload between May 1 and May 15 each year, depending on the weather. Unloading is indicated by the increased pumping required to remove sludge from the secondary clarifier. While unloading is going on, the quality of effluent from the plant deteriorates a little, the effect on the other units of the plant being shown by tests as follows:

ondary filter (1½-in. stone) when both filters are running in parallel as low-rate filters. Over a 3-month period, a series of tests showed the average B.O.D. from the primary filter as 80 p.p.m.; from the secondary filter, 128 p.p.m.

*Secondary Clarifier*

The secondary clarifier has run continuously since put into operation in 1940. No trouble has been experienced with any of the mechanical equipment. The plant became overloaded by supernatant late in the summers of 1946 and 1947, a condition that prevailed practically all through the summer of 1948. During these periods, the surface of the secondary clarifier was covered with scum or floating sludge. The effluent from the secondary clarifier, under these conditions, had a B.O.D. of 50 p.p.m. or more. Previous to this time the B.O.D. of the secondary clarifier effluent was about 20 p.p.m. Overloading of the unit, either by storm

| Date | Filter Condition | B.O.D. (p.p.m.) | | | | Susp. Solids (p.p.m.) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Raw Sewage | Primary Effl. | Sec. Effl. | Final Effl. | Raw Sewage | Primary Effl. | Sec. Effl. | Final Effl. |
| 5/28/42 | Unloading | 320 | 166 | 37 | 23 | 180 | 176 | 72 | 32 |
| 6/ 3/42 | Unloaded | 280 | 120 | 18 | 7 | 192 | 98 | 14 | 6 |
| 5/18/44 | Unloading | 340 | 173 | 51 | 23 | 188 | 88 | 32 | 13 |
| 6/12/44 | Unloaded | 520 | 260 | 20 | 8 | 276 | 174 | 28 | 14 |

Circular filters would be preferable to the present octagonal ones for two reasons: (1) filter flies breed more freely in the unused corners; and (2) ice forms in them, especially when there is any appreciable amount of snow. Even though filter flies are very noticeable around the filter and the siphon chamber, they are not much of an annoyance, as they seldom get as far as the office building, about 200 ft. away.

The tests show that the primary filter (2½-in. stone) produces a greater reduction in B.O.D. than does the sec-

flows or by extra strong sewage, does not seem to cut down its effectiveness.

*Magnetite Filter*

The magnetite filter is usually started about May 15th each year and shut off about Nov. 1st, although it could be run throughout the entire year if needed. No special mechanical trouble has been experienced during its 8 years of operation. Every second year about ½ bbl. of magnetite sand is added to replace that used during the operation.

The magnetite filter is the stop-gap

for the plant. It can be depended on to effect a sizeable reduction in B.O.D., regardless of the strength of the sewage that comes to it. For example, during 1948, when the plant was badly overloaded with sludge overflows from the digester, the magnetite filter reduced the suspended solids from 71 p.p.m. to 12 p.p.m. and the B.O.D. from 56 p.p.m. to 14 p.p.m. During normal plant operation in the summer of 1944 the magnetite filter reduced the suspended solids from 24 p.p.m. to 6 p.p.m. and the B.O.D. from 6 p.p.m. to 4.9 p.p.m. Whenever such marked reduction of B.O.D. or suspended solids is not needed, this unit can be shut off by removing an aluminum gate and draining the unit. Also, it can be started at any time of the year on a moments' notice, so is really the operator's indispensable unit.

*Screen and Grit Chamber*

The screen and grit chamber causes more work for the operator than any other unit in the plant. The screen operates every 30 min. during the summer months and by hand switch in winter. Screenings have been placed in an old settling tank for years, but it is planned to burn them in the new municipal incinerator after its completion this year.

A new Parshall flume was installed ahead of the screen in 1943. Since that time, sand and gravel have been backing up in the 30-in. sewer line. It is intended to install a comminutor some time in the near future and use the screen chamber for removal of sand and gravel only.

*Sludge*

Sludge handling at this plant went through several stages of development. The unheated digester tanks provided when the plant was built in 1931 were inadequate in size and the sludge drawn off did not dry readily. A 35-ft. diameter, 20,000-cu. ft. capacity, heated digester constructed in 1940 worked very satisfactorily for 4 years, but began to show the effects of overloading in the late summer of 1945. The condition became increasingly worse each summer until a new 50-ft. diameter digester with a capacity of 40,000 cu. ft. was built in 1948. The newest tank will be used as a primary digester, with the old 35-ft. unit as a secondary digester.

The 35-ft. digester produced 7,000 cu. ft. of gas per day in winter and 12,000 cu. ft. per day in summer. This would indicate a winter population of about 7,000 and about 12,000 in summer, which is higher than the estimate on which the plant was designed. Gas production has been adequate for heating both the digesters and the office building.

By 1936 it was evident that the two covered sludge drying beds (6,500 sq. ft.) constructed in 1931 were inadequate. A 50-sq. ft. vacuum filter installed in 1939 was operated with varying degrees of success until the end of 1948. A new coil spring type vacuum filter of 150-sq. ft. area was installed in the spring of 1949. When this filter is working properly it is planned to take down and sell the covered drying beds.

*Operating Costs*

The Liberty plant is operated by one man during 9 months of the year; during the three summer months one helper is provided. Some additional labor is required to clean the sludge drying beds and for repair work. In 1948 the total labor charge, including operators, was $4,780; the charge for power was $1,800, and for materials and other items, $1,000. The average appropriation for operation of the plant for the past five years has been $7,500. With an increase in wages and increase of power used for new units of the plant, the average annual cost of operating the plant will probably be $8,500.

## DISCUSSION

By Wallace W. Sanderson

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Rather than a discussion of the paper on the Liberty sewage treatment plant, it may be of greater interest to present the studies of the receiving stream conducted by the Division of Laboratories and Research, New York State Department of Health, before and after the installation of the bio-filters.

The plant effluent is discharged into the upper reaches of the Middle Mongaup River, a small mountain brook having a drainage area of 6 sq. mi. above the point of discharge. The brook passes through the village of Liberty before it reaches the plant site. In general, the stream is shallow and the flow is rapid and turbulent, although there are places in the first mile below the outfall where it deepens and quiet flow results in deposition of solids. Flow measurements made in 1935 showed a minimum of 1.4 m.g.d.; later observations indicated an average summer flow of about 5 to 8 m.g.d. This is greatly increased during other seasons of the year and after rainfall.

A primary treatment plant was built in 1931 and operated as such until 1935. Numerous complaints regarding the condition of the river were received from owners of bordering land and, in an effort to remedy the condition, a study of chemical coagulation with alum and iron salts was made. The process was adopted and a marked improvement occurred in the quality of the effluent. In 1940, a high-rate filter plant was built with the intention of operating it without recirculation during the winter months.

The first studies were made in 1935 prior to chemical treatment. At that time, not all the industrial wastes and sewage entered the sewers. An appreciable amount of pollution was present in the stream above the plant outfall, although insufficient to be noticeable to the ordinary observer. The discharge of settled sewage markedly discolored the stream, making it gray and turbid, with a strong septic odor. Black, gassing deposits had formed on which *Tubifex* and *Chironomas* worms were numerous. In other words, the stream was septic—a condition which prevailed for 6,000 ft. below the outfall, at which distance the brook flowed over rapids and soon returned to a condition similar to that of the upper section before addition of sewage.

In 1940, 4 years after chemical treatment was put in use, the stream above the sewage plant was in excellent condition. All wastes had either been intercepted or the industries abandoned. The color was a light natural brown, with very little turbidity. However, the sewage plant effluent still discolored the water, which became gray and turbid; sludge deposits were present; odors were noticeable, although generally resembling sewage rather than septic conditions. It was obvious that the brook was badly polluted, but the distance polluted and the degree were much less than before chemical treatment. Passage over the rapids removed all evidences of pollution.

Inspections during the winter of 1940–41, when the high-rate filters were operating without recirculation, showed a marked reduction in the color and turbidity of the effluent. The stream below the outfall was discolored for only about 1,000 ft. Sludge deposits decreased but did not disappear; odors were absent. With the advent of warm weather in 1941 and complete operation of the high-rate filtration process, marked improvement occurred. All visible evidence of pollution was absent 1,000 ft. below the outfall. Sludge

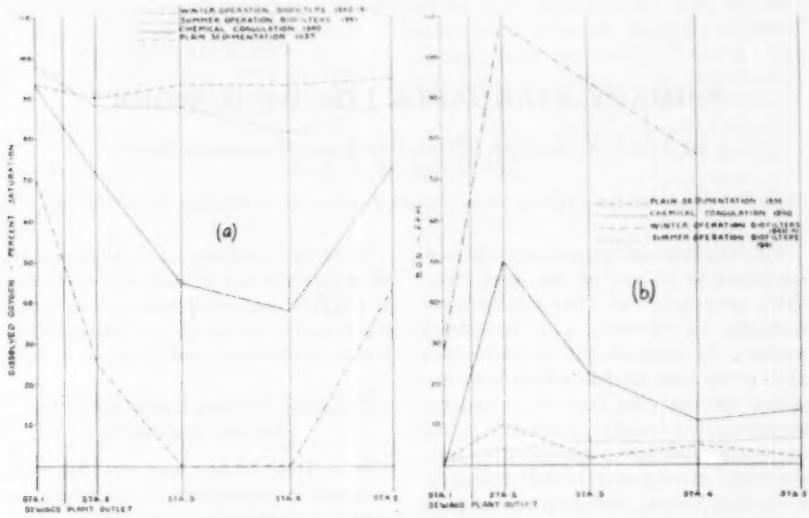


**FIGURE 1.—Middle Mongaup River survey showing: (a) dissolved oxygen determinations; (b) biochemical oxygen demand.**

deposits persisted until the end of July, after which they disappeared completely. *Tubifex* and *Chironomas* worms were absent and no odor could be detected. A subsequent inspection in 1942 showed this condition had continued and all visible evidence of the sewage effluent disappeared 50 ft. below the plant outfall.

Complete chemical, bacteriologic, and biologic examinations of samples collected at various stations on the stream were made on each inspection, but the results can well be demonstrated by schematic diagrams of the dissolved oxygen and B.O.D. results (Figure 1). Stations 2, 3, 4, and 5 were, respectively, 1,000, 2,000, 4,000, and 7,000 ft. below the outfall. Figure 1a shows that in 1935, previous to chemical treatment, some reduction of oxygen occurred above the plant. Rapid reduction to complete depletion 2,000 ft. below followed the sewage discharge, and recovery did not occur until after passage over the rapids between Stations 4 and 5. In 1940, the effect of chemical treatment is shown by a marked reduction in the oxygen sag and recovery to a much greater degree in passing over the rapids. The dramatic result of high-rate operation is shown by the results in the winter months of 1940–41, although some of this must be attributed to the greater dilutions and lower temperatures prevailing. However, that such improvement could be maintained is shown by the results in the summer of 1941 when the lowest dissolved oxygen was 83 per cent of saturation, as compared to complete depletion the previous years.

Similarly, Figure 1b shows gross pollution previous to 1935. Chemical treatment and elimination of unsewered pollution reduced the load on the brook in 1940, but the values still indicated a badly polluted stream. Again, the results of winter operation of the high-rate filter plant are reflected by a remarkable improvement in the quality of the water. Continuation of the improvement during the next two years was accompanied by a disappearance of all evidence of previous pollution.

# PRIMARY STANDARDS FOR B.O.D. WORK*

By Clair N. Sawyer, Peter Callejas, Maryalice Moore, and Albert Q. Y. Tom

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The biochemical oxygen demand test continues to be one of the most valuable measures of the pollutional strength of sewage and industrial wastes. In spite of the developments within the past decade which have resulted in the adoption of a mineral supplemented water containing all necessary nutrient elements (1), considerable discrepancy is still found in analytical results obtained on samples of the same waste when submitted to analysis at different laboratories. Although the difference is sometimes due to variations in nitrification, as has been shown by various investigators (2) (3) (4), there are other important reasons for divergent results even when nitrification is not involved.

There are actually five basic requirements which a B.O.D. dilution water must possess—proper salinity and pH; reasonable buffer capacity; presence of necessary nutrient elements (nitrogen, phosphorus, etc.); absence of toxic substances such as copper, chlorine, chloramines, etc.; and presence of a viable and balanced seeding matter. From experiences in this and other laboratories, it is felt that the present "Standard Methods" (5) dilution water does satisfy the first three requirements in an admirable manner. However, the fourth and fifth requirements are left to each analyst to satisfy to the best of his ability and, therefore, constitute sources of major discrepancies at the present time.

It is the purpose of this paper to show how the use of standard solutions of organic matter prepared from pure compounds can be used to standardize B.O.D. techniques and results.

## Selection of Pure Compounds for Primary Standards

It is well known that the basis of volumetric analytical chemistry in many cases depends on the use of primary standards consisting of pure compounds that can be weighed with great accuracy and then used to standardize the vital reagent used in the test. In the B.O.D. test, the vital reagent is the B.O.D. dilution water, from which oxygen is abstracted in proportion to the biological action under way. Therefore, the primary standard should be one that can be used to stimulate biological action in the B.O.D. dilution water. Many organic compounds suggest themselves for this use.

For convenience, the organic compounds studied were limited to glucose and sucrose representing the carbohydrates, to peptone, and to six amino acids. Preliminary studies showed that sucrose possessed no advantage over glucose so it was dropped from further consideration, as was peptone because of its uncertain composition.

Glucose, glycine, glutamic acid, phenylalanine, cystine, hydroxyproline, and methionine were studied, as well as mixtures of each of the amino acids in combination with glucose. The results are shown in Table I. It was found that methionine exhibited a very

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**TABLE I.—Biochemical Behavior of Certain Pure Substances Tested for Primary Standards in B.O.D. Work**

| Compound | Per Cent of Theoretical B.O.D. Exhibited in 5 Days at 20°C. | |
|---|---|---|
| | By Itself | With Glucose |
| Glucose, U.S.P. | 66.5 | — |
| Glucose, C.P. | 70.0 | — |
| Glycine | 73.0 | 69.9 |
| Glutamic acid | 71.0 | 69.6 |
| Phenylalanine | 71.2 | 71.5 |
| Methionine | 11.9 | 59.0 |
| Cystine | 75.4 | 70.3 |
| Hydroxyproline | 60.6 | 63.0 |

low percentage (7 to 15%) of its theoretical B.O.D. during the usual 5-day incubation test. Hydroxyproline gave about 60 per cent of its theoretical B.O.D. and cystine showed variable results. The results given by these three amino acids in combination with glucose were somewhat more satisfactory, but inferior to other substances under test. Consequently, subsequent studies were concentrated on glucose, glycine, glutamic acid, and phenylalanine. These data also show that a C.P. grade of glucose is preferable to a U.S.P. grade.

Solutions containing 300 p.p.m. of glucose, of glycine, of glutamic acid, and 150 p.p.m. of phenylalanine, and one to one mixtures of each of the amino acids solutions with the glucose solution were analyzed for B.O.D. on nine occasions using 3-, 5-, and 10-ml. portions in the standard 300-ml. bottles.

The data obtained involved 27 determinations of B.O.D. on each solution tested. The data were analyzed statistically, the results showing that the standard deviation was less than 5.3 per cent of the mean in all cases. Application of the null hypothesis at the probability level of 0.95 to the data showed no significant difference between the B.O.D. values obtained with varying dilutions of sample, except in the case of glycine where the differences in data for the 3- and 10-ml. portions were large enough to be significant.

Thus, the four substances—glucose, glycine, glutamic acid and phenylalanine—and mixtures of the amino acids with glucose satisfied the preliminary test procedure for B.O.D. primary standards.

## Final Selection of Primary Standards

It is obvious from the above test procedure that reproducibility was the major consideration under a given set of conditions which were thought to be very good. No attempt was made to determine the ability of the various

**TABLE II.—Effect of Deficiencies and Toxic Substances on B.O.D. of Primary Standards**

| Primary Standard | Change in B.O.D. (p.p.m.) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $Cu^{++}$ | | $CrO_4^{=}$ | | Chloramine | | $Pb^{++}$ | $HgCl_2$ | P | $NH_3$-N | Limited Seed |
| | 0.1 p.p.m. | 0.2 p.p.m. | 1.0 p.p.m. | 5.0 p.p.m. | 0.005 p.p.m. | 0.08 p.p.m. | 0.2 p.p.m. | 0.5 p.p.m. | 0.00 p.p.m. | 0.00 p.p.m. | 0.5 ml. per l. |
| Glucose | −16 | −47 | −18 | −50 | −20 | −63 | −12 | −74 | −22 | −52 | −10 |
| Glycine | + 4 | − 5 | −16 | −13 | + 3 | −16 | − 4 | −36 | − 4 | +10 | − 3 |
| Glutamic acid | −15 | −15 | −22 | −60 | − 9 | −29 | −11 | −77 | −16 | −32 | −14 |
| Phenylalanine | −14 | + 3 | −10 | −21 | − 4 | −31 | 0 | −58 | − 7 | −19 | + 4 |
| *Mixtures* | | | | | | | | | | | |
| Glucose-Glycine | − 5 | − 6 | −10 | −20 | − 5 | −37 | − 3 | −52 | −11 | −20 | − 6 |
| Glucose-Glutamic acid | −11 | −12 | −10 | −32 | 0 | −47 | −13 | −74 | −23 | −37 | + 3 |
| Glucose-Phenylalanine | − 4 | −11 | −18 | −21 | −10 | −62 | + 2 | −67 | −16 | −45 | 0 |

substances to indicate deficiencies or toxicity of the dilution water.

To determine the sensitivity of the various candidate primary standards to detect such adverse conditions as may occur in practice, B.O.D. determinations were run with a deficiency of seed, of nitrogen, and of phosphorus, and also in the presence of toxic compounds and ions such as chloramines, copper, mercuric chloride, lead, and chromates. The results of these studies are shown in Table II.

From the data in Table II, it will be seen that the mixtures of amino acids with glucose showed no advantages over certain of the individual pure substances and were especially poor indicators of limited amounts of seeding matter. Of the pure compounds, glucose and glumatic acid were most sensitive toward toxic copper, chloramine, and a deficiency of seed, as well as being good indicators of other limitations. Therefore, it is concluded that glucose and glutamic acid will serve as useful primary standards for B.O.D. work.

## The Use of Glucose and Glutamic Acid Primary Standards

The technical grades of glucose and glutamic acid are not satisfactory for B.O.D. standards. It is recommended that a C.P. or Analytical grade glucose and C.P. glutamic acid (Eastman Kodak) be used for primary standards, and that they be oven dried at 103°C. for 1 hr. before use.

Solutions containing 300 p.p.m. of either of these substances can be prepared with ease, and in such concentration lend themselves nicely to direct pipetting into the B.O.D. bottles. The recommended portions in 300-ml. bottles are 5 ml. or 10 ml.

From the great number of analyses run on such solutions in the laboratory, it is believed that the glucose solution should exhibit a 5-day, 20°C. B.O.D. of 224 p.p.m., ± 11 p.p.m., or about 70 per cent of the theoretical B.O.D. ($L$ = 320 p.p.m.), and that the glutamic acid solution should exhibit a 5-day, 20°C. B.O.D. of 217 p.p.m., ± 10 p.p.m., or about 73.8 per cent of the theoretical B.O.D. ($L$ = 294 p.p.m.). Any appreciable divergence from these values is a warning signal. These quantities would indicate $k$ values of 0.102 and 0.116, respectively, showing only traces of nitrification in the incubated bottles. A $k$ of 0.1 would give a 5-day B.O.D. of 217 p.p.m. for the glucose solution, and 200 p.p.m. for the glutamic acid solution.

## Practical Application of Primary Standards

From the start of these investigations, it has been hoped that the primary standards might allow calculation of an activity coefficient that could be applied to correct values for each batch of B.O.D. results in the same manner as might be done in analytical chemistry by applying strength factors where a relatively unstable standard reagent (such as $KMnO_4$) is used. However, in view of the experiences with the primary standards, such a strength factor or activity coefficient does not appear to be easily obtained and a word of caution concerning the interpretation of data obtained with glucose and glutamic acid primary standards in B.O.D. work seems in order.

As the B.O.D. test depends on biochemical reactions in a wide variety of media, it does not necessarily follow that the same effect is produced by a given set of conditions in the various media. Some study of this factor has been made and the results are given in Table III. These data show that the presence of a given toxic material in a dilution water does not necessarily influence the B.O.D. of various materials to the same degree. For instance, 0.5 p.p.m. of $HgCl_2$ depressed the B.O.D. of glutamic acid to 67 per cent of that

**TABLE III.—Effect of Toxic Materials on 5-Day B.O.D.**

| Substrate | Control | Toxic Substances | | | | | |
|---|---|---|---|---|---|---|---|
| | | $HgCl_2$ 0.05 p.p.m. | | $Cu^{++}$ 0.1 p.p.m. | | $CrO_4^{=}$ 5.0 p.p.m. | |
| | | p.p.m. | %[1] | p.p.m. | %[1] | p.p.m. | %[1] |
| Glucose, 300 p.p.m. | 188 | 152 | 81 | 157 | 84 | 167 | 89 |
| Glutamic acid, 300 p.p.m. | 195 | 130 | 67 | 135 | 69 | 155 | 80 |
| Kier liquor | 13,000 | 11,100 | 86 | 10,400 | 80 | 10,500 | 81 |
| Rag-rope waste | 20,000 | 18,700 | 93 | 16,700 | 83 | 16,600 | 83 |
| Sewage | 162 | 152 | 94 | 118 | 73 | 127 | 78 |

[1] Per cent of control values.

shown by the control, whereas the same concentration of $HgCl_2$ allowed 94 per cent of the normal B.O.D. of a sewage sample to be exhibited. Copper ion and chromate ion showed somewhat similar results. Thus, it does not appear that a simple correction factor can be applied properly to all situations. The role of the primary standards would seem to be as an aid in indicating the presence of such toxic materials, followed by their elimination from the dilution water in subsequent tests.

Domestic sewage of various ages and in different concentrations has been recommended for seeding dilution water. The discrepancy between test results obtained at different laboratories has led to suspicion that such seeding material is not uniform in character and viability. To check on this characteristic, sewage samples have been obtained from some twenty locations in Massachusetts and used for seeding purposes in determining the B.O.D. of the primary standards. Some of the results (Table IV) show that considerable variation does exist in the ability of the sewage seeds from different sources to produce the same B.O.D. on identical solutions. It is to be noted that when low results were obtained with one primary standard low results were obtained with the other. These data illustrate the important role the primary standards can serve in eliminating the use of sewages from unsatisfactory sources for seeding material. Furthermore, the standards can materially assist in establishing optimum age and concentration of sewage to use for seeding purposes.

**TABLE IV.—Effectiveness of Sewage as Seed for Dilution Water**

| Source of Sewage[1] | 5-Day B.O.D. of Standard Solutions (p.p.m.) | |
|---|---|---|
| | Glucose, 300 p.p.m. | Glutamic Acid, 300 p.p.m. |
| Boston[2] | 224 | 217 |
| Worcester | 225 | 216 |
| Leominster | 215 | 215 |
| Fitchburg | 207[3] | 207 |
| Clinton | 185[3] | 194[3] |
| Ayer | 194[3] | 180[3] |
| Hudson | 185[3] | 168[3] |
| Attleboro | 240[3] | 224 |
| Greenfield | 232 | 212 |

[1] All in Massachusetts.
[2] Ward Street.
[3] Values considered abnormal or beyond range of experimental error.

## Summary

Glucose or glutamic acid solutions (300 p.p.m.) are admirably suited for serving as standard solutions in B.O.D. work. Such solution will indicate the presence of toxic substances in the dilution water, deficiencies of nitrogen or phosphorus, and the viability of the seeding material used.

## Acknowledgment

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## AIR POLLUTION COURSE

An inservice training course in Air Pollution, the first to be offered on this subject by the School of Public Health, University of Michigan, will be held February 6, 7, and 8, 1950, at Ann Arbor, Mich. This is the thirty-third in a series of inservice, non-credit, training courses offered by the University's School of Public Health.

The course, which is being given at the suggestion of workers in the field of study of the problems, relates to identification of the problem, the tools used in investigation and determination of solution of problems, and the approach employed in solution of some of the problems involving common industrial and other sources of air pollution. Although necessarily somewhat technical in character, the course is intended to serve personnel of a wide variety of interests, such as air pollution control and other public officials, industrial communities, industrial hygiene personnel who render service in this field, and sanitary engineers, especially those concerned with the disposal of industrial wastes.

# EXPERIENCE WITH MODIFIED METHODS FOR B.O.D.*

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The second, or nitrogen stage of the B.O.D. determination has been recognized as a disturbing influence in the 5-day result for some years and its significance has been widely discussed. The approach of nitrification, or primarily nitrosification, may greatly increase the measured B.O.D., the increase being roughly proportional to the concentration of ammonia nitrogen and the activity of nitrifying bacteria. The increase may be very great in sewage effluents or river waters that have reached the stage of incipient nitrification, so that results show a considerably increased B.O.D. even though the sample may be more completely treated than it had been when the ammonia was higher and no nitrification had started.

The senior author commented on this in 1939 (1) and the problem had been recognized in the laboratories of the Sanitary District of Chicago five or ten years before this date. Activated sludge effluents are rarely completely nitrified, but are usually in the first stage of B.O.D., sometimes just ready to nitrify. Then, especially during warm summer conditions, the oxidation of ammonia may occur more or less completely during the period of incubation and the B.O.D. may be doubled or increased several hundred per cent.

This condition has also been very noticeable in the Illinois River studies. The zone of nitrification has been moving upstream and results in excessive B.O.D. values at certain stations, far above what might be expected in an orderly satisfaction of B.O.D. by self-purification. The significance of these increased results will be discussed later, but for the present the discussion involves the work done on the depression of the second stage.

## Depression of Second-Stage B.O.D.

Procedures proposed for depressing nitrification that have been investigated are:

1. Pasteurization and reseeding (2).
2. Acidification, neutralization, and reseeding (3).
3. Chromium salts (4) (5) (6).
4. Methylene blue (7).
5. Copper salts.
6. Sodium chloride.
7. Organic bactericides.

The first three methods have been studied at length and in detail, and some studies are being made of the fourth method. The others appear to be rather remote possibilities, as copper salts are too toxic, sodium chloride is not effective in low amounts, and organic additions are uncertain.

The first criterion to be considered is whether the modification depresses nitrification but does not give low results with raw or settled sewage more than five days prior to incipient nitrification.

The first study, in 1940, compared pasteurization and acid treatment, first on settled sewage and then on activated sludge effluents. The results, shown in Tables I and II, indicated very little depression by either method on settled sewage and about the same correction

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by either pasteurization or acidification on activated sludge effluents. The technique of pasteurization is more involved than acid treatment; consequently the latter method was used for a number of years in the plant laboratories and Illinois River laboratories, in comparison with the "standard" method (8), which has never been supplanted by any of the modified methods.

In seeding the acidified, neutralized samples, fresh settled sewage has always been used, never effluent or river water, which obviously would re-introduce nitrifying bacteria. The seeded water should have a loss of about 0.5 to 1.0 p.p.m. of dissolved oxygen.

Sawyer and Bradney (2) used the pasteurization technique in 1945 at Sioux Falls, where highly nitrogenous packinghouse wastes intensified the nitrogen problem and gave excessive B.O.D. results for effluents and downstream river samples.

The acid and pasteurization methods have always appeared to check in the authors' investigations, but no methods used give a correction which checks with the decrease in unoxidized nitrogen, computed to oxygen. The nitrogen oxidation often fails to equal the oxygen demand increase. This has been ascribed to synthesis of organic matter, including the effect of photosynthesis if light is present, but this increase is relatively low compared with the oxygen equivalent of nitrogen loss. Therefore, nitrogen oxidation is considered to be the predominant cause of excessive B.O.D. results.

TABLE I.—Effect of Acidification and Pasteurization on B.O.D. of Raw Sewage (1940)

| Test No. | Untreated | Pasteurized | Acidified to pH 2-3 |
|---|---|---|---|
| 1 | 32 | 52 | 32 |
| 2 | 45 | 39 | 49 |
| 3 | 58 | 54 | 56 |
| 4 | 100 | 100 | 98 |
| 5 | 83 | 70 | 84 |
| 6 | 118 | 109 | 121 |
| 7 | 84 | 84 | 84 |
| 8 | 235 | 235 | 225 |
| 9 | 67 | 66 | 70 |
| Aver. | 91 | 90 | 91 |

TABLE II.—Effect of Acidification and Pasteurization on B.O.D. of Activated Sludge Effluent (1940)

| Test No. | Untreated | Pasteurized | Acidified to pH 2-3 | $NO_2$—N | $NO_3$—N |
|---|---|---|---|---|---|
| 1 | 13.7 | 0.8 | 3.0 | tr. | 8.0 |
| 2 | 12.2 | 7.0 | 8.5 | 1.6 | 7.2 |
| 3 | 10.3 | 6.3 | 4.3 | 0.6 | 3.4 |
| 4 | 8.3 | 3.4 | 4.5 | 0.6 | 5.4 |
| 5 | 28.0 | 11.5 | 12.8 | 0.6 | 2.4 |
| 6 | 12.6 | 8.8 | 7.0 | 0.5 | 0.7 |
| 7 | 32.0 | 19.0 | 12.8 | 0.6 | 0.5 |
| 8 | 22.0 | 7.0 | 6.2 | 1.7 | 1.5 |
| 9 | 15.8 | 3.8 | 3.8 | 1.2 | 1.5 |
| Aver. | 17.2 | 7.5 | 7.0 | — | — |

## Chromium Salts

The effects of chromium on biological oxidation have been studied at length during the past ten years, particularly the effect of various amounts of chromium on the activated sludge process. Amounts from 2 to 10 p.p.m. (as Cr) have been stated to prevent nitrification and lower amounts are inhibitory (4) (5) (6). These observations led to work on the effect of dichromate on B.O.D., and gave a rough approximation of concentrations that might be used.

TABLE III.—Effect of Chromium on B.O.D.; Seeded Dilution Waters

| Chromium (p.p.m.) | Pairs of Samples | 5-Day B.O.D. (p.p.m.) | | Modified (% of Std.) |
|---|---|---|---|---|
| | | Standard | Modified | |
| 0.2 | 4 | 0.9 | 0.85 | 95 |
| 0.3 | 5 | 1.5 | 1.45 | 94 |
| 0.4 | 3 | 1.61 | 1.57 | 96 |
| 0.5 | 5 | 1.61 | 1.49 | 90 |
| 0.8 | 1 | 1.4 | 1.3 | 93 |
| 1.0 | 30 | 1.75 | 1.62 | 92 |
| 1.2 | 1 | 1.6 | 1.45 | 91 |
| 1.5 | 6 | 1.68 | 1.5 | 89 |
| 2.0 | 3 | 2.0 | 1.77 | 86 |

**TABLE IV.—Summary of Results on Seeded Dilution Waters and Illinois River Samples Comparing Regular, Acid Modified, and Dichromate Modified [1] B.O.D.**

| Station | Number of Samples | 5-Day B.O.D. (p.p.m.) | | Increase in $NO_3-N$ [2] (p.p.m.) | Oxygen Equiv. of Increase in $NO_3-N$ [3] (p.p.m.) | 5-Day B.O.D. (p.p.m.) | |
|---|---|---|---|---|---|---|---|
| | | Regular | Dichromate Modified Samples | | | Corrected Dichromate Modified Samples | Acid Modified Samples |
| Seeded dil. | 60 | 1.75 | 1.62[4] | — | — | — | — |
| Henry | 28 | 7.5 | 3.7 | 0.15 | 0.5 | 3.2 | 2.2 |
| Lacon | 27 | 6.6 | 3.2 | 0.10 | 0.3 | 2.9 | 2.0 |
| Peoria | 28 | 5.0 | 2.8 | 0.05 | 0.2 | 2.6 | 2.0 |
| Pekin | 23 | 6.2 | 3.2 | 0.08 | 0.3 | 2.9 | 2.0 |

[1] Samples containing 1.0 p.p.m. Cr.
[2] In dichromate modified over acid modified samples, as N.
[3] In dichromate modified samples, N −3 to N +3, as O.
[4] Dichromate modified B.O.D. of seeded dilution waters averaged about 92 per cent of regular B.O.D.; May 6 to June 30, 1948, inclusive.

Ruchhoft (9) in 1948 described experiments in which dichromate was used in B.O.D. studies and indicated it might be of value to depress nitrification.

The river studies at Peoria, Ill., were changed to study dichromate instead of acid as the inhibitory agent, and have been continued to date. The first study was completed at Peoria, July 12, 1948, to compare the effect of various amounts of chromium on the B.O.D. The results, given in Tables III and IV, indicate little difference between 0.3 and 1.0 p.p.m. Cr, with increasing depression at 2.0 p.p.m. As a result of further tests it was concluded that 1.0 p.p.m. would be needed to depress the rather strong nitrification present in this sample in July.

Further studies were made on raw sewage at the Chicago Southwest treatment works. The results are shown in Table V, wherein the depression is quite noticeable, 1.0 p.p.m. chromium giving a B.O.D. only 87 per cent of the standard.

A further test was made at the Southwest works comparing 1.0 p.p.m. chromium with acid treatment (Table VI). This showed only 87 per cent of the standard by the chromium modi-

**TABLE V.—Effect of Chromium on B.O.D.; Chicago Southwest Treatment Works**

| Test No. | 5-Day B.O.D. (p.p.m.) | | | | |
|---|---|---|---|---|---|
| | Cr 0.0 | Cr 0.25 | Cr 0.50 | Cr 1.00 | Cr 2.00 |
| 1 | 102 | 98 | 85 | 97 | 93 |
| 2 | 113 | 107 | 101 | 107 | 107 |
| 3 | 114 | 102 | 100 | 100 | 98 |
| 4 | 183 | 72 | 67 | 73 | 70 |
| 5 | 79 | 68 | 63 | 62 | 67 |
| 6 | 203 | 200 | 185 | 180 | 180 |
| 7 | 290 | 275 | 255 | 260 | 245 |
| 8 | 158 | 155 | 138 | 140 | 145 |
| 9 | 195 | 185 | 175 | 160 | 160 |
| 10 | 283 | 260 | 233 | 235 | 208 |
| Aver. | 162 | 152 | 140 | 141 | 137 |
| % of Std. | — | 93.8 | 86.4 | 87.0 | 84.5 |

**TABLE VI.—Effect of Chromium (1 P.P.M.) Compared with Acid Treatment; Chicago Southwest Treatment Works**

| Test No. | Control | Chromium | Acid Neutralized |
|---|---|---|---|
| 1 | 165 | 140 | 153 |
| 2 | 198 | 175 | 183 |
| 3 | 245 | 210 | 240 |
| 4 | 313 | 265 | 288 |
| 5 | 122 | 104 | 117 |
| 6 | 111 | 102 | 107 |
| 7 | 165 | 153 | 168 |
| 8 | 170 | 160 | 170 |
| 9 | 147 | 118 | 137 |
| Aver. | 182 | 159 | 174 |
| % of Std. | — | 87.4 | 95.5 |

TABLE VII.—Effect of Chromium (1 P.P.M.) and Acid Treatment; Chicago West Side Imhoff Effluent

| Test No. | Control | Chromium | Acid Neutralized |
|---|---|---|---|
| 1 | 89 | 81 | 86 |
| 2 | 90 | 82 | 87 |
| 3 | 90 | 85 | 90 |
| 4 | 84 | 80 | 84 |
| 5 | 90 | 86 | 90 |
| 6 | 80 | 70 | 80 |
| 7 | 110 | 92 | 107 |
| 8 | 81 | 78 | 80 |
| 9 | 83 | 75 | 81 |
| Aver. | 89 | 81 | 87 |
| % of Std. | — | 91 | 97.8 |

fication; 92 per cent was found at Peoria, but recovery of 95.5 per cent was obtained by the acid method, a much more satisfactory comparison.

Previous comparative tests using acid had shown even closer correlation. Therefore another set of standard-acid comparative results was run on Imhoff tank effluent from the West Side plant, as it was suspected that recirculation of activated sludge may have seeded the raw sewage at the Southwest plant with nitrifying bacteria. The results on the West Side Imhoff effluent (Table VII) showed that the acid treatment almost exactly checked the standard, as had been found previously.

## Acid and Chromium Modifications, Illinois River Samples

Studies of acid modification on Illinois River samples in the Peoria area had been started in July, 1946, but were dropped from Nov., 1946 to Feb., 1947, then continued until June, 1948. Since June, 1948, dichromate (as 1.0 p.p.m. chromium) has been used. A map of the Illinois River is shown in Figure 1. Results of the modified B.O.D., expressed as per cent of the standard B.O.D., are given in Figure 2.

The work was done at four stations, with incipient nitrification strongest at Henry, but considerably decreased farther downstream at Peoria and Pekin, where products of photosynthesis are present. Figure 2 shows the general trend; namely, a very great correction in summer, when temperatures stimulate nitrification, but less correction in winter at lower temperatures.

These observations are more clearly illustrated by the curve for Henry (Figure 3). The summer results, using acid, are only about 25 per cent of the standard (Table VIII), whereas the chromium result is about 36 per cent. In winter the percentages average 65 per cent for acid and 68 per cent for chromium.

The results at Henry are shown in Figure 4. The modified method gave results from 2 to 3 p.p.m. both summer and winter, depressing the tremendous summer increases, due largely to nitrification, up to 7 to 10 p.p.m. It will be noted that the chromium results (Figure 3) showed a higher percentage of the standard in the summer of 1948 than did the acid modification in the summers of 1946 and 1947. The acid modification thus seems to give more depression in the section of the river where nitrification is more active, at the same time giving practically no depression of sewage B.O.D. at Chicago. Results at intermediate stations fall between these two extremes.

On the other hand, chromium gave less correction at downstream stations, but resulted in a depression in the results at Chicago or intermediate stations that was larger than that noted by the acid modification (see Tables VI and VII).

These studies show that the chromium seems to be generally depressive, not being completely effective on nitrifying bacteria but affecting the entire flora, including the organisms present in raw or settled sewage as well as in nitrifying effluents or downstream river samples.

On the other hand, acid treatment conforms more closely to the desired distinction between raw and nitrifying sewage; that is, it does not depress the

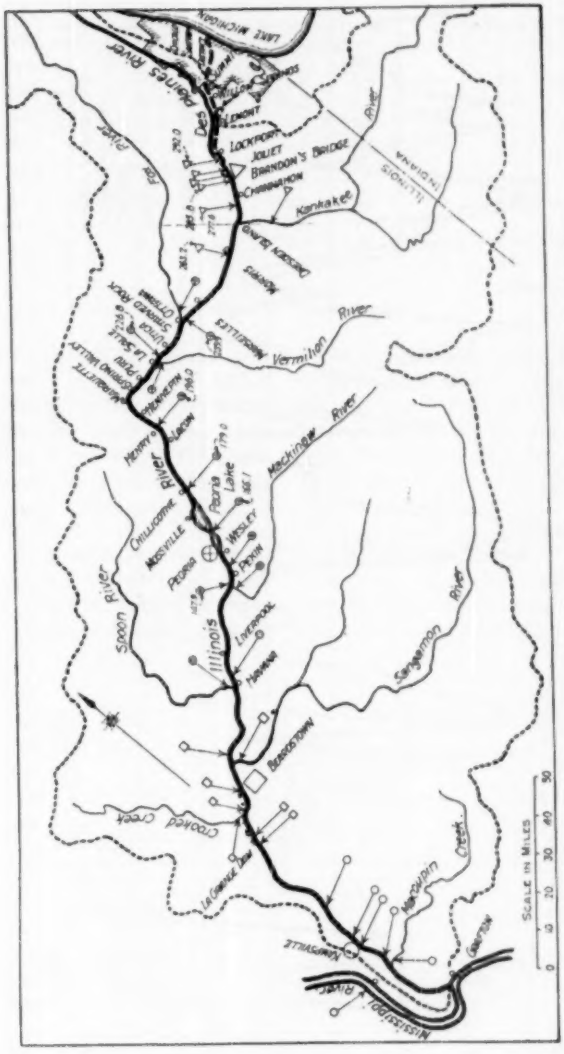


FIGURE 1.—Des Plaines-Illinois River gaging and sampling locations.

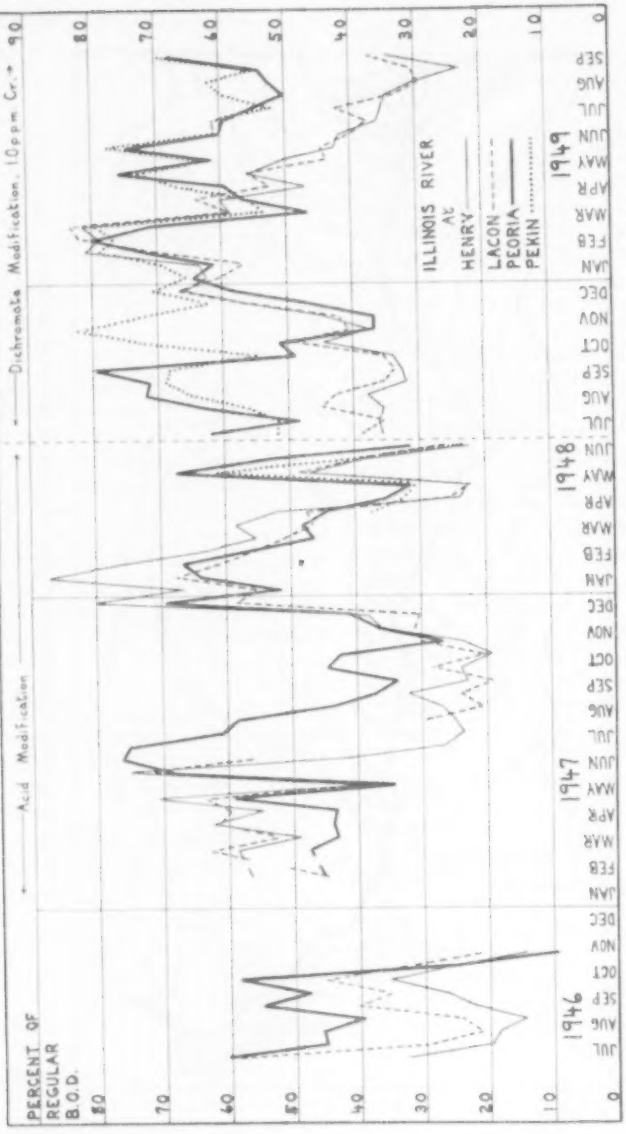


FIGURE 2.—Modified 5-day B.O.D. compared with regular B.O.D. of Illinois River water; half-month averages.

**TABLE VIII.—Summer and Winter Analyses, Illinois River**

| Period | Dissolved Oxygen (p.p.m.) | | | | 5-Day B.O.D. (p.p.m.) | | | | Per Cent of Standard | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Lockport | Morris | Henry | Peoria | Lockport | Morris | Henry | Peoria | Henry | Peoria |
| Summer[1] | | | | | | | | | | |
| 1946 | 0.0 | 5.2 | 6.5 | 8.5 | 13.9 | 5.5 | 8.4 | 7.6 | 24.6 | 47.3 |
| 1947 | 0.0 | 5.2 | 5.6 | 6.9 | 18.7 | 4.5 | 9.3 | 5.9 | 25.1 | 49.5 |
| 1948 | 0.2 | 6.3 | 6.3 | 8.1 | 8.0 | 4.3 | 6.3 | 5.1 | 35.9 | 61.9 |
| Aver. | 0.05 | 5.6 | 6.1 | 7.8 | 13.5 | 4.8 | 8.0 | 6.2 | 28.5 | 52.9 |
| Winter[2] | | | | | | | | | | |
| 1946 | 0.9 | 11.2 | 12.4 | 12.5 | 16.8 | 5.1 | 4.4 | 4.5 | — | — |
| 1947 | 1.9 | 11.6 | 12.0 | 11.8 | 13.2 | 4.4 | 4.0 | 3.4 | 65.5 | 55.2 |
| 1948 | 1.2 | 11.3 | 12.2 | 12.1 | 12.5 | 3.5 | 4.4 | 4.1 | 68.4 | 62.4 |
| Aver. | 1.3 | 11.4 | 12.2 | 12.1 | 14.2 | 4.3 | 4.3 | 4.0 | 67.0 | 58.8 |

[1] July to October, inclusive. [2] December to March, inclusive.

B.O.D. of raw or settled sewage, but does give a very great depression of nitrifying samples, in fact even greater than the chromium modification. The acid treatment is therefore more efficient, but it must be recognized that the technique of acid modification is more involved than that of chromium treatment. A good deal depends on the precaution that the seeding sewage should not contain nitrifying bacteria or be near the stage of nitrification.

Chromium thus appears to be questionable as a specific agent to depress nitrification. To a certain extent this is true of all depressants. Methylene blue was considered by Abbott (7) to be specific, because Phelps used it in his stability studies, but Abbott used 3 p.p.m. as compared with 1.3 p.p.m. used by Phelps. It would be of interest if further work or study proves methylene blue to be of specific toxicity toward nitrifying bacteria.

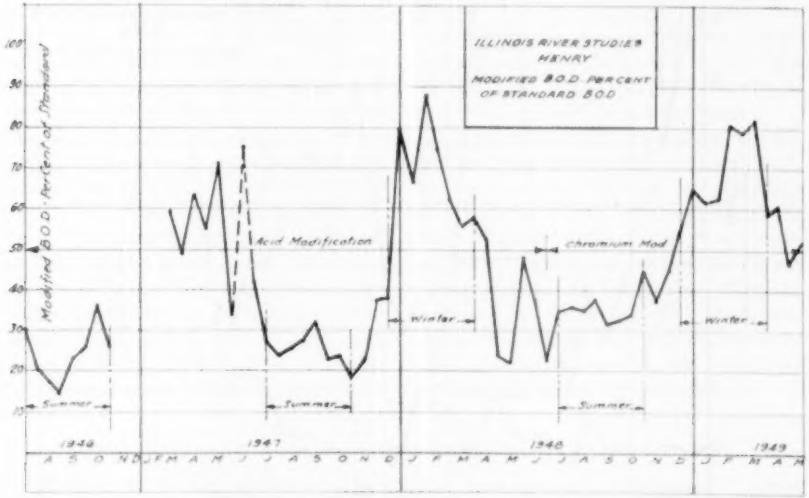


FIGURE 3.

This seems to be the desirable line of study for modified B.O.D., to distinguish between carbon oxidation and nitrogen oxidation. Some agent is needed that in minute quantity will completely eliminate the nitrifying forms, but will not appreciably change the flora which determines the carbonaceous B.O.D. Standard and modified B.O.D. determinations could be made with more assurance than is now possible that there is not merely inhibition of the B.O.D. of all samples.

### Significance of Modification

Although considerable interest has been devoted to the question of modification of B.O.D., practically, as far as the Illinois River is concerned, the modification is unnecessary.

Nitrate is formed largely from the oxidized nitrogen, and the potential oxygen in the nitrate is rightly considered an asset for streams where only prevention of a nuisance is the objective. The dissolved oxygen can be depleted to zero, but the reserve of nitrate will prevent nuisance conditions until utilized. However, if dissolved oxygen is the standard and it must not be allowed to go below 3 or 4 p.p.m., nitrate will be of no particular use as it will not be drawn upon until the dissolved oxygen is completely used.

### Dissolved Oxygen Balance

In the Illinois River the B.O.D. shows an increase at Henry over that at Morris, due to nitrification. However, the depletion of dissolved oxygen is slower than that noted in the first-stage B.O.D. (lower reaction velocity) and, therefore, reaeration gives a slight increase, instead of a loss, of D.O.

In Table VIII and Figure 5 it will be noted that the B.O.D. at Morris is 4.8 p.p.m.; at Henry, 8.0 p.p.m. In spite of the increase of 3.2 p.p.m. B.O.D., the dissolved oxygen shows a slight increase of 0.5 p.p.m., indicating that reaeration has satisfied much of

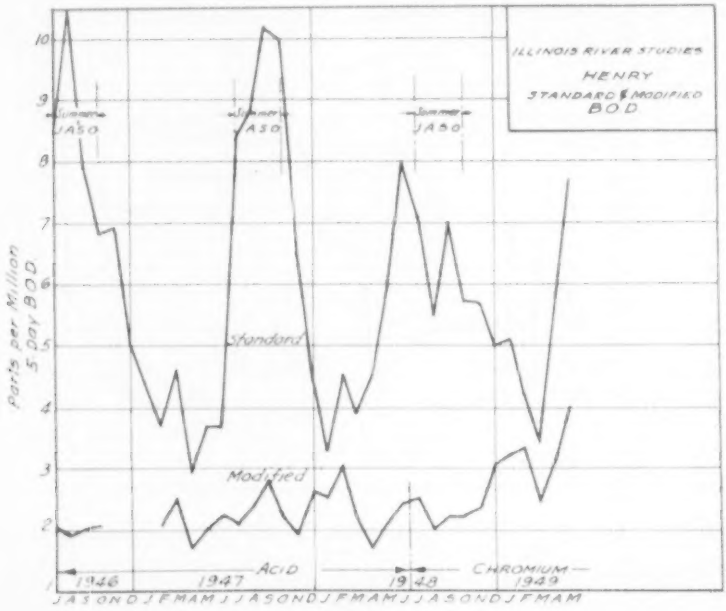


FIGURE 4.

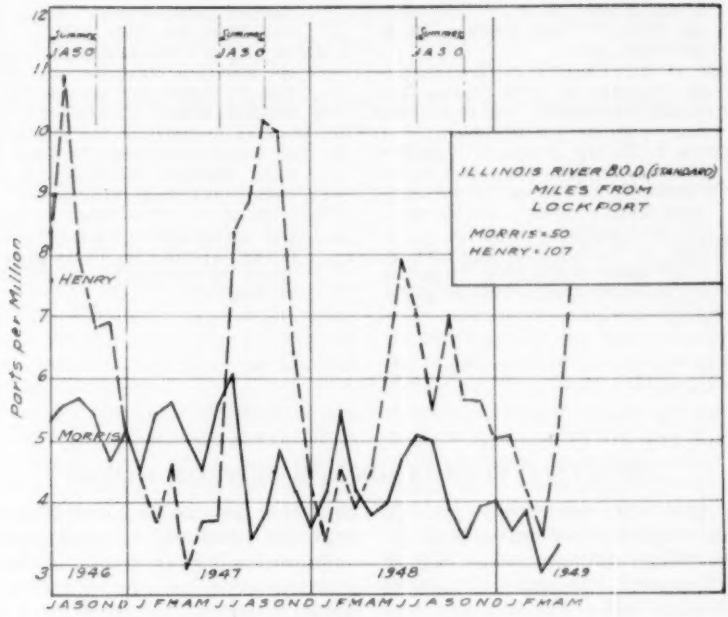


**FIGURE 5.**

the increased B.O.D. However, the modified B.O.D. would be only 2.3 p.p.m., which is too low to be representative of actual conditions.

It must be concluded, therefore, that one would not be justified in overlooking the nitrogenous B.O.D. under Illinois River conditions or wherever fish life is concerned. It would be of interest to have both carbonaceous and nitrogenous B.O.D., because of the difference in rates of reaction, and because the nitrogenous result (nitrate) at least would prevent odor nuisance in the stream. For dissolved oxygen balance, however, the ammonia must be considered a liability. It is also questionable whether the ammonia should be oxidized more or less completely in an activated sludge plant because the resulting nitrate is just as undesirable as a stimulant of unwanted secondary growths. Also, the cost of ammonia oxidation, even when it can be accomplished easily, adds greatly to the cost of activated sludge oxidation only to the point of incipient nitrification.

Modified B.O.D., therefore, should not be reported in Illinois River studies and has only more or less academic interest. However, it would be of interest if some corollary test or interpretation of results could be developed which would indicate the stage of nitrification of the sample. It is wondered if, perhaps, the oxidation-reduction potential would be sensitive enough to indicate this condition.

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## TENTATIVE STANDARDS FOR SEWAGE WORKS

In what may well be a major step toward adoption of sewage works design standards on a national basis, a 37-page report entitled "Tentative Standards for Sewage Works" has been submitted by a joint Committee on Development of Uniform Standards for Sewage Works, representing the Upper Mississippi River Board of Public Health Engineers and the Great Lakes Board of Public Health Engineers. The present draft is not intended as a final authoritative document, but as a preliminary work for careful review by consulting engineers and others. The Committee, composed of a representative from each state health department comprising the two Boards, hopes that the constructive criticism received will enable it to prepare acceptable sewage works design standards that will eliminate the present confusion encountered by consulting and designing engineers practicing in several states.

Major headings covered in the tentative standards include: submission of plans; design and construction of sewers; design of lift stations; and design and construction of treatment works and the component units. Under the last phase, special groupings include preliminary treatment units, sedimentation, sludge digestion and disposal, and secondary treatment facilities.

Consulting engineers interested in securing copies of the tentative standards may secure them on request from the state health department of any of the states that have combined to produce them. The ten states represented in one or both of the two Boards are Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, and Wisconsin.

# DISPOSAL OF SEWAGE EFFLUENT AT MADISON, WIS.*

By H. O. Lord

*Chief Engineer and Director, Madison Metropolitan Sewerage District, Madison, Wis.*

The purpose of this paper is to give an historical account of the disposal of sewage and of sewage effluent at Madison, Wis., and to raise the question as to what the ultimate requirement may be in providing satisfactory sewage treatment.

Sewerage facilities at Madison are provided by Madison Metropolitan Sewerage District, which embraces an area of about 60 sq. mi. and includes the City of Madison, four villages, and parts of five townships. Madison is known locally as the Four Lakes City because of its proximity to a chain of lakes (Mendota, Monona, Waubesa, and Kegonsa) forming a part of the Yahara River system, which drains southward to the Rock River and thence into the Mississippi River.

The disposal of sewage in Madison and adjoining territory, and the maintenance of the adjacent lakes as free as possible from sewage pollution, is a matter of grave importance to all residents in the vicinity. The history of sewage disposal in the area has been a continuous effort on the part of its citizens to prevent and abate nuisances and menaces to public health, and is an excellent example of the development of modern sewerage in the United States.

The need for improvement in municipal sanitation received general recognition in the United States late in the 19th century, and it was about 1880 or earlier that sewers were constructed within the city limits by groups of private citizens. In 1884, the city requested plans for a general system of sewage disposal. Two plans were submitted—one for treatment by broad irrigation, or farm treatment; the other, by chemical precipitation.

The city was unable to proceed immediately with either plan, but did proceed to create small sanitary districts under a state law enacted about that time. As a consequence, by 1887, at which time Madison had a population of 12,000, there were 18 such districts in the city served by public sewers, which discharged raw sewage directly into either Lake Mendota or Lake Monona. As the need for a more unified method of collection and transmission and for an improved method of sewage disposal became pressing, the city in 1895 authorized a general sewerage system, including sewage treatment works utilizing chemical precipitation.

The sewerage system was constructed and the city's first sewage treatment plant was placed in operation about May, 1898. This plant was one of the earliest sewage treatment plants utilizing chemical precipitation in this country. The plant was operated until January 1, 1901, when it was abandoned and rejected by the city because it failed to meet certain guarantees of performance under which it had been constructed.

The plant was replaced by one consisting of a septic tank and cinder trickling filters, and credited with being the first trickling filter plant in the United States. Effluent from the plant flowed into the Yahara River at a point between Lake Mendota and Lake Monona (see Figure 1). Due to

* Presented at 22nd Annual Convention, Central States Sewage Works Association; Chicago, Ill.; June 17–18, 1949.

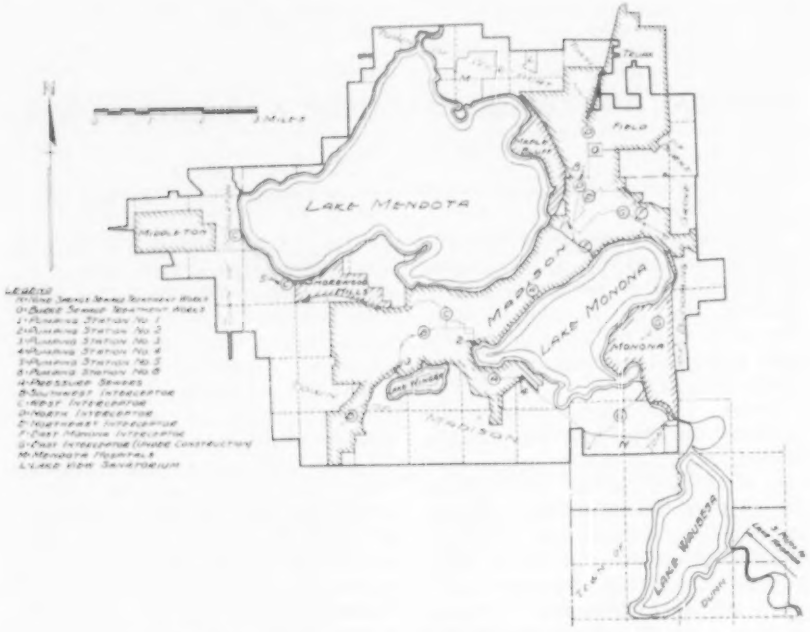


FIGURE 1.—Madison (Wis.) Metropolitan Sewerage District.

increased population, the plant was superseded in 1914 by a new 5-m.g.d. plant, known as the Burke plant, located northeast of the city and consisting of sludge separating tanks, sludge digestion tanks, and stone trickling filters. It discharged its effluent into the mouth of the Yahara River at Lake Monona.

Additional sewage treatment was soon required because of continuing growth of the city and in 1928, the Nine Springs sewage treatment plant was placed in operation. This plant had a rated capacity of 5 m.g.d. so that the sewage treatment facilities of the city had a total rated capacity of 10 m.g.d.

The Nine Springs sewage treatment plant is located south of the city and as first built consisted of Imhoff tanks, stone trickling filters, and final clarification tanks. Effluent from the plant flows into the Yahara River at a point between Lakes Monona and Waubesa.

Until 1928, the sewerage problem of the area was regarded as a local problem of the City of Madison. At that time, however, due to the growth of the several municipalities in the area, the question arose as to the most feasible way of disposing of sewage from the metropolitan area. This resulted in 1930 in the creation, under Wisconsin statutes, of Madison Metropolitan Sewerage District, a public unit governed by three commissioners appointed by the County Court for terms of three years.

The District acquired from the City of Madison in 1933 its sewage treatment facilities and certain intercepting sewers. By 1936 additions had been made to the Nine Springs sewage treatment works and improvements had been completed to sewage pumping stations so that the Burke plant could be discontinued. The addition to the Nine Springs treatment works consisted of an activated

sludge type plant rated at 6.25 m.g.d. to operate in parallel with the original plant. Treatment facilities were further increased in 1939 when additions to the activated sludge plant increased the total capacity to about 15 m.g.d.

### Burke Plant in Temporary Use

The present sewerage facilities are essentially as they were in 1939 with one exception. During World War II, the U. S. Army rehabilitated the Burke plant and used it. The plant has since reverted to the District, which is using it until the transmission and treatment facilities are increased by construction now under way on a 7-mi. intercepting sewer around the easterly side of Lake Monona to the Nine Springs works, where additions are being made to the activated sludge plant. This new construction is scheduled for completion by the spring of 1950, when use of the Burke plant again will be discontinued.

From this brief resume, it is apparent that the citizens of Madison and vicinity have been alert to the need for sewage works and that the communities have been aggressive in providing and maintaining modern and adequate sewerage and sewage treatment facilities.

### Lake Problem

There is, however, in conjunction with the sewage problem, another problem of public interest in the Madison area—the condition of the lakes in the vicinity, particularly as regards algal growths, fish life, and odors. As the population of the area has increased residents have become more and more lake conscious. Actually, there are five lakes in the Madison area—those previously mentioned and Lake Wingra, a smaller lake draining to Lake Monona. All are hard water lakes, and all are subject to algal growths in varying degrees of profusion. Decomposition of the growths causes odors of different degrees of obnoxiousness, so that many people believe that the conditions are due to the discharge of sewage effluent into the lakes. This belief has persisted in spite of the fact that the District discharges no sewage effluent into either Lake Mendota, which has an area of about 15 sq. mi., or Lake Wingra, which has an area of about 0.5 sq. mi.

In 1941 and 1942, as a result of complaints to the effect that sewage effluent was responsible for the obnoxious algal conditions, Madison Metropolitan Sewerage District appropriated $20,000 to finance a study of algal growths and other conditions in the local lakes. This work was carried on under the direction of a committee appointed by the Governor of Wisconsin and under the immediate supervision of Professor Clair N. Sawyer. Two reports were made covering the periods July, 1942 to July, 1943 and July, 1943 to July, 1944. The committee in its second report said, "These investigations have not found an answer to nuisance control on the lakes, but they have determined the sources from which the food materials for the growth of algae which produce the nuisance are derived and the quantity contributed by each. They have brought out strong supporting data for the opinion that the most important nutrient substances are soluble nitrogen and phosphorus and if it were possible to remove these substances from the wastes themselves it would effect a marked decrease in incidence and density of algal growth and thereby contribute significantly to the abatement of the nuisance caused by their growth."

The report further stated that in view of the fact that some of these were laboratory experiments only, and others were made on the lakes where many uncontrollable factors were exercising an influence, the study had reached that phase which was referred to in the beginning as the "long-time problem." The committee then continued with a statement to the effect that the long-

time problem was considered to be a problem concerning the state and therefore should properly be financed by funds provided by the legislature, inasmuch as the studies thus far made had unearthed facts the further study of which would appear to offer a solution of the problem, not only for the City of Madison and Dane County, but also for many other communities in the state. It recommended that the legislature be requested to provide funds to continue the investigation and studies under more natural conditions than afforded by many of the laboratory experiments.

## Legislation

No funds were forthcoming, but the legislature enacted Chapter 69, Laws of Wisconsin, 1943, which reads as follows:

"AN ACT to repeal and recreate 144.05(1) of the statutes, relating to the pollution of Wisconsin lakes.

The people of the state of Wisconsin, represented in senate and assembly, do enact as follows:

Section 1. 144.05(1) of the statutes is repealed and recreated to read:

144.05(1) When any city or village or owner shall have constructed or shall in the future construct a sewage system complying with section 144.04, the outflow or effluent from such system may be discharged into any stream or drain constructed pursuant to law, but no such outflow or effluent or raw or treated sewage from a city or metropolitan sewage district comprised of 45,000 persons or more, shall be discharged directly into, or through any stream, or through any drain, into a lake of more than 2 square miles and less than 6 square miles in area located within 10 miles of the system or plant of such city, or metropolitan sewage district.

Section 2. This act shall take effect one year after the termination of the present war as proclaimed by the President or the Congress of the United States.

Approved April 20, 1943."

It will be noted that no consideration is given in the law to whether the effluent is highly polluted or highly purified, and that the law appears to have been drawn specifically for the Madison communities, where the areas of Lakes Monona, Waubesa, and Kegonsa fall within the limits set.

On July 16, 1948, the State Board of Health and the Committee on Water Pollution of the State of Wisconsin issued a joint order to the Madison Metropolitan Sewerage District ordering the preparation of plans for eliminating the discharge of sewage effluent into Lakes Monona, Waubesa, and Kegonsa in accordance with the provisions of the law.

The Commissioners of the District were advised that the law was invalid, that there was grave doubt as to the validity of the order, and that the District was not justified in making the expenditures for the proposals set forth in the order until its validity had been passed upon by the courts. The District thereupon petitioned for a review of the necessity and reasonableness of the order by the issuing agencies. Following the hearing, the state agencies on Sept. 7, 1948, affirmed their order of July 16, 1948, in all respects except that the last date for submission of preliminary plans was extended to December 31, 1948, and the date for the submission of completed plans was extended to June 30, 1949.

Among the findings of fact, the second order of the joint agencies stated that the sewage treatment facilities of the District consist of primary and secondary treatment resulting in the production of an effluent of satisfactory biological oxygen demand and bacteria content, but which nevertheless contains inorganic nitrogen and inorganic phosphorus; that while the sewage effluent is treated according to the most accepted methods known to modern sanitary engineering it is nevertheless necessarily rich in inorganic phosphorus and inorganic nitrogen, which cannot be readily separated or eliminated from such effluent; that

such inorganic phosphorus and inorganic nitrogen in the quantities discharged by the District treatment plants into the waters of Lakes Monona and Waubesa contribute highly to the growth of blue-green algae of the type that results in serious nuisance conditions in Lakes Monona, Waubesa, and Kegonsa; and that the removal or diversion of said sewage effluent from the waters of the above named lakes will diminish nuisance conditions in said lakes by reducing the frequency and intensity of the algal blooms.

### Petition for Judicial Review

The Commission then filed a petition for judicial review under the statute, and among other things alleged: "That said order is not based on any violation by the district of any lawful standard relating to treatment of sewage or disposal of sewage effluent, nor upon any claimed violation of any requirement made by any existing statute or lawful regulation relating to the treatment of sewage or disposal of sewage effluent; that the Madison Metropolitan Sewerage District asserts the right to continue to discharge sewage effluent from its modern, up-to-date, sewage and disposal plants of the quality and characteristics currently being produced at said plants into the waters of the natural drainage area in which the district is located. . . ."

The Court found that the order of the State agencies was contrary to the constitutional rights of the petitioners; made in excess of the statutory authority or jurisdiction of the state agencies; and made and promulgated upon unlawful procedure. It thereupon reversed the order.

An appeal by the state agencies from the court order is now pending before the Wisconsin Supreme Court.

### Further Legislation

On March 8, 1949, there was introduced in the State Senate a bill to amend the foregoing Chapter 69, Laws of 1943, with reference to the date on which the act becomes effective by providing that all necessary construction for full compliance with the order shall be completed by November 1, 1950. A substitute amendment was subsequently adopted by the Senate as follows:

The people of the state of Wisconsin, represented in senate and assembly, do enact as follows:

Chapter 69, laws of 1943, is amended and re-enacted to read:

"144.05(1) of the statutes is amended to read:

144.05(1) When any city or village or owner shall have constructed or shall in the future construct a sewage system complying with section 144.04, the outflow or effluent from such system may be discharged into any stream or drain constructed pursuant to law, but no such outflow of untreated sewage or effluent from a primary or secondary treatment plant from a city or metropolitan sewage district comprised of 45,000 persons or more shall be discharged directly into, or through any stream, or through any drain, into a lake of more than 2 square miles and less than 6 square miles in area located within 10 miles of the system or plant of such city, or metropolitan sewage district. All necessary construction of plant, system or drains for full compliance with this subsection in the discharge of untreated sewage or sewage effluent from all existing primary or secondary plants shall be completed by June 1, 1951, and the plans for any new system or plant shall include provisions for compliance with this subsection. The state committee on water pollution shall have the power and authority at any time to order and require any owner of an existing plant to prepare and file with it, within a prescribed time, preliminary or final plans or both, for proposed construction to comply with this subsection. In lieu of the construction in compliance with the foregoing provision for diversion from such lakes, any owner of an existing plant, on or before June 1, 1950, or any owner of a new system or plant prior to construction of such new system or plant, may file with the committee on water pollution

such plans for advanced treatment of effluent from primary or secondary treatment as in the judgment of said committee will accomplish substantially the same results in eliminating nuisance conditions on such a lake as would be accomplished by diversion of secondary sewage effluent from said lake (without at the same time creating other objectionable or damaging results), and such owner shall be exempt from the foregoing provisions of this subsection for diversion from such lakes upon approval of such plans and installation of advanced treatment facilities and procedures in compliance therewith, provided that nothing shall impair the authority of said committee to require at any time preliminary or final plans or both, for diversion construction. Any person violating the provisions of this subsection or any order issued in furtherance of compliance therewith shall forfeit to the state not less than $100 nor more than $500 for each violation, failure or refusal. Each day of continued violation shall be deemed a separate offense. No such penalty shall be invoked during the time that any petition for review of an order is pending under section 144.56 until final disposition thereof by the courts, if judicial review is sought under chapter 227."

The bill has been passed by the Senate and is now before the Assembly for consideration.*

It is of interest that in 1948 the University of Wisconsin undertook a research project covering a study of conditions in Wisconsin lakes, with particular reference to fish life, fertilization, weeds, and algal growths. As a part of this project an attempt is being made to find a practical means of providing a third or tertiary stage of sewage treatment for the removal of nutrient materials from sewage plant effluent.

This summarizes briefly the history of the disposal of sewage effluent at Madison. Two questions are posed:

1. What constitutes satisfactory sewage treatment?

2. To what limits may municipalities and industries be required to go in an attempt to effect satisfactory sewage treatment?

* The substitute amendment as passed by the Senate was subsequently passed by the Assembly and approved by the Governor, becoming Chapter 435, Laws of 1949.

## CONFERENCE ON POLLUTED IRRIGATION WATERS

On January 27, 1950, there will be held in El Paso, Texas, a conference on polluted irrigation waters. The meeting is being sponsored jointly by the Environmental Health Study Section, U. S. Public Health Service; the El Paso, Texas, Health Department; and the Texas State Health Department.

The program will be devoted to discussions of general problems on irrigation waters in several western and southwestern states; current research relative to the incidence and behavior of pathogenic organisms in irrigation waters, vegetable washings, and soils; discussion of epidemiological aspects of sewage polluted irrigation waters. In addition, papers will be presented on the utilization of waste water, impounding and use of water of the Rio Grande, machines for vegetable washing, present standards for irrigation water, and use of sewage sludges for soil improvement.

All persons interested in this phase of environmental health are cordially invited to attend the meeting. Copies of the program may be obtained from Mr. Irving Gerring, Executive Secretary, Environmental Health Study Section, Division of Research Grants and Fellowships, National Institutes of Health, Bethesda 14, Md.

# CONTROL OF BACTERIAL NUMBERS IN CHLORINATED SEWAGE EFFLUENTS

By Rolf Eliassen [1] and Herman L. Krieger [2]

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In a previous paper (1), a method was developed for the evaluation of the results of the disinfection of sewage effluents by chlorination. It was shown that a rational method for the control of the chlorination process was to maintain a fixed value of chlorine residual in the sewage effluent after a given contact period in order to achieve stipulated coliform kills. The purpose of the research reported herein was to develop the above method to the point where it could be applied to practice —in this case, to the primary clarifier effluent from the sewage treatment plant at Ridgewood, N. J.

Relationships were developed between chlorine dosages and chlorine residuals at various contact periods and the most probable number (M.P.N.) of coliform organisms per 100 ml. of effluent. Such relationships, when developed for specific plants, would enable designing engineers to make an economic comparison between the cost of retention tanks for each contact period and the cost of chlorine. They would also serve as a guide to plant operators in determining chlorine dosages and chlorine residuals necessary to comply with the M.P.N. requirements of regulatory bodies having jurisdiction over the abatement of stream pollution.

[1] Now Professor of Sanitary Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

[2] Now Sanitary Chemist, Environmental Health Center, U. S. Public Health Service, Cincinnati, Ohio.

## Experimental Procedure

Samples of primary clarifier effluent were obtained from Ridgewood, N. J., on twelve different days and at different hours during the days. The chlorine demand of each sample was determined by the orthotolidine test, using the standard 10-min. contact time. Each sample was divided into four 1-liter portions. Chlorine solution was added to each portion at dosages equal to 100, 133, 167, and 200 per cent of the chlorine demand. At the end of each of five specified contact periods—namely, 5, 10, 15, 20, and 30 min.—50-ml. portions were withdrawn aseptically into sterile sample bottles. Each bottle contained 0.5 ml. of a 10 per cent solution of sodium sulfite, which reduced the remaining chlorinous compounds to inactivity.

At the time of withdrawal of each 50-ml. portion, chlorine residuals were determined by means of orthotolidine. Analyses were made of each portion for the M.P.N. of coliform bacteria using the partially confirmed test, with brilliant green lactose bile as the confirmatory medium. Four dilutions, with three tubes at each dilution were used on a single sample to determine the M.P.N. of coliform organisms. The validity of this technique has been justified in the previous paper (1).

## Sewage Characteristics

The sewage used in these experiments was a fresh domestic sewage having an average B.O.D. of 110 p.p.m.

TABLE I.—The M.P.N. per 100 Ml. Coliform Bacteria and Chlorine Demand of Primary Settled Sewage from Ridgewood, N. J.

| Experiment No. | Chlorine Demand (p.p.m.) | M.P.N. per 100 Ml. |
|---|---|---|
| 1 | 4.6 | 2.5 M |
| 2 | 5.4 | 4.5 M |
| 3 | 6.4 | 950 T |
| 4 | 3.0 | 950 T |
| 5 | 3.4 | 450 T |
| 6 | 4.2 | 2.5 M |
| 7 | 4.2 | 9.5 M |
| 8 | 5.2 | 25 M |
| 9 | 6.8 | 25 M |
| 10 | 6.6 | 9.5 M |
| 11 | 6.4 | 25 M |
| 12 | 7.0 | 9.5 M |

Note: M = million, T = thousand.

after passing through a settling tank with a detention time of approximately 1 hr. The chlorine demand and the M.P.N. of coliform bacteria of the samples obtained on each of the twelve days are shown in Table I.

## Results

These experiments involved a total of 240 separate runs. To conserve space, no attempt will be made to present the individual results, except for one contact period as an example. The chlorine residuals obtained on each of the twelve days' samples have been averaged for each of the four dosages and the five contact periods. Residual values in each group were so close that arithmetic averages are justified. The average 10-min. chlorine demand of the sewages noted in Table I was 5.3 p.p.m. This is equivalent to the average chlorine dosage in the first series of runs at 100 per cent of the chlorine demand.

TABLE II.—Average Chlorine Residuals with Various Contact Periods and Chlorine Dosages

| Chlorine Dosage | | Average Residual Chlorine (p.p.m.) | | | | |
|---|---|---|---|---|---|---|
| Percentage of Chlorine Demand | Average (p.p.m.) | Contact Period (Min.) | | | | |
| | | 5 | 10 | 15 | 20 | 30 |
| 100 | 5.3 | 0.14 | 0.10 | 0.08 | 0.05 | 0.04 |
| 133 | 7.0 | 0.56 | 0.52 | 0.50 | 0.46 | 0.42 |
| 167 | 8.8 | 1.22 | 1.20 | 1.14 | 1.07 | 1.01 |
| 200 | 10.6 | 1.80 | 1.77 | 1.74 | 1.69 | 1.63 |

Table II presents the average chlorine dosages and residuals obtained in these experiments.

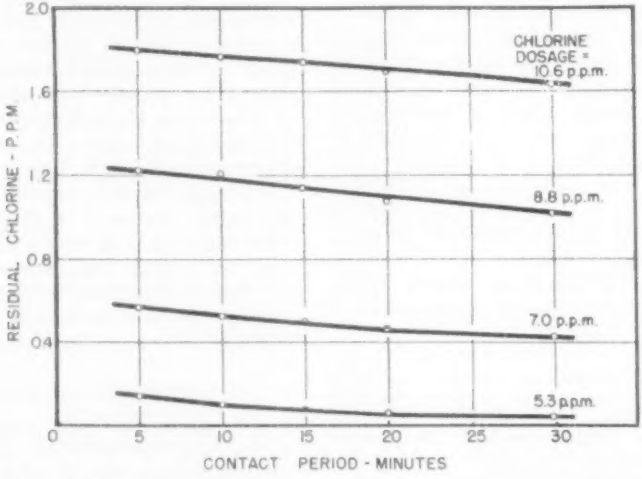


FIGURE 1.—Effect of contact time on residual chlorine at various chlorine dosages.

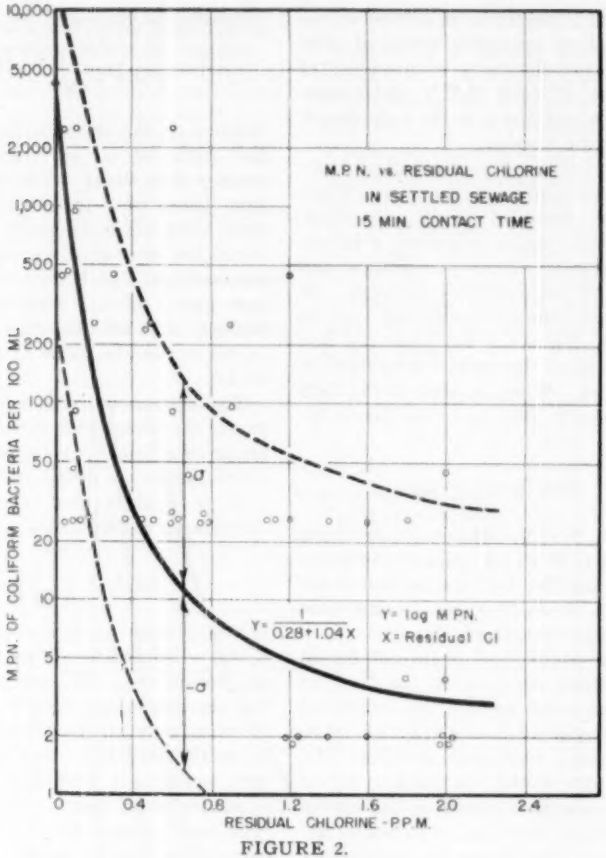


FIGURE 2.

These results have been plotted in Figure 1, which shows the rate of decrease in chlorine residuals with time. Each curve represents the average chlorine dosage noted, corresponding to 100, 133, 167, and 200 per cent of the average chlorine demand. Each point on the curve represents the average of twelve runs.

In Figure 2 the results of M.P.N. and residual chlorine determinations have been plotted for each of the 48 runs at the 15-min. contact period. The nature of bacteriological analyses is such that the results are frequently diverse but exhibit a definite trend. In Figure 2 this trend is downward to the right, more or less within the limits of the two dotted lines shown, representing one standard deviation, $\sigma_y$, from the mean. Because of their diversity, the results cannot be averaged, but must be resolved by statistical methods.

Similar curves were drawn for the data from the 5-, 10-, 20-, and 30-min. contact periods, but are not published in this paper. These graphs were interpreted in the manner described for the 15-min. contact period.

### Evaluation of Bacteriological Data

In order to arrive at the curve of best fit for the data shown in Figure 2, the method of least squares was

employed. Inasmuch as M.P.N. values are based on geometric ratios of dilutions, it was desirable to consider the logarithm of each M.P.N. determination when relating it to the corresponding chlorine residual.

Various types of mathematical functions were applied to the data. These functions included linear, potential, expotential, and reciprocal relationships between chlorine residuals and the M.P.N. of coliform bacteria. It was found that the reciprocal type of function, $1/y = a + bx$, gave the best fit when all of the contact periods were considered. When applied to the data in Figure 2, this function takes the form

$$\log N = \frac{1}{a + bR}$$

in which $N$ is the M.P.N. of coliform organisms, $R$ is the chlorine residual by orthotolidine test, and $a$ and $b$ are constants depending on contact time and sewage characteristics.

The comparison of degree of fitness of the linear equation in the form of $\log N = a \pm bR$ against the reciprocal curve mentioned above may be made by standard statistical methods (2). By computing the standard error of the estimate, $S_y$, for each of the curves and relating these to the standard deviation $\sigma_y$, the degree of correlation may be measured. For the straight line this is known as the coefficient of correlation, $r$; for any curvilinear function it is known as the index of correlation, $\rho$. In both cases, the relationship is expressed by

$$r, \text{ or } \rho = \sqrt{1 - \frac{S_y^2}{\sigma_y^2}}.$$

Because $S_y$ can never be larger than $y$, the ratio of $S_y^2/\sigma_y^2$ can never be greater than unity. The smallest possible value of $r$ or $\rho$ would occur if there were no relationship existing between the two variables—namely, chlorine residual and M.P.N.—at each contact time. If the relationships were perfect, and all observed points fell on the curve, the value of $r$ or $\rho$ would be 1.0.

The results of correlation tests between the linear and reciprocal curvilinear equations for residual vs. M.P.N. relationships are shown in Table III.

It is evident that the reciprocal curvilinear relationships,

$$\log N = \frac{1}{a + bR},$$

is better than the linear equation, $\log N = a - bR$, when all contact periods are considered. The reciprocal equation descends more rapidly as residuals increase, showing the pronounced effect of small residuals. Similar comparisons were made with the other types of curves noted above. The reciprocal relationship gave the best fit for all except the 5-min. period and consequently was adopted for each contact period.

Standard methods of statistical analysis (2) were employed in arriving at the value of $a$ and $b$ for each of

TABLE III. Comparison of the Characteristics of Linear Correlations and Reciprocal Curvilinear Correlations

| Contact Time (min.) | $S_y^2$ | | $\sigma_y^2$ | | $r$ | $\rho$ |
|---|---|---|---|---|---|---|
| | Linear | Reciprocal Curvilinear | Linear | Reciprocal Curvilinear | Linear | Reciprocal Curvilinear |
| 5 | 1.134 | 0.192 | 1.512 | 0.240 | 0.52 | 0.45 |
| 10 | 0.952 | 0.649 | 1.230 | 0.899 | 0.48 | 0.53 |
| 15 | 0.526 | 0.672 | 0.664 | 1.180 | 0.45 | 0.66 |
| 20 | 0.542 | 1.132 | 0.732 | 1.552 | 0.51 | 0.52 |
| 30 | 0.671 | 1.554 | 0.671 | 1.640 | 0.00 | 0.23 |

**TABLE IV.—Values of Constants in Reciprocal Curvilinear Equation Expressing the Relationships of M.P.N. and Residual Chlorine for Various Contact Periods**

| Constant | Contact Time (Min.) | | | | |
|---|---|---|---|---|---|
| | 5 | 10 | 15 | 20 | 30 |
| $a$ | 0.17 | 0.21 | 0.28 | 0.65 | 1.91 |
| $b$ | 0.32 | 0.74 | 1.04 | 1.02 | 0.47 |

the contact periods. These values are noted in Table IV. The curves resulting from these equations are presented in Figure 3.

## Prediction of Disinfection Results

Assuming a normal distribution of results of bacteriological analyses, where chance alone governs the deviation from the curves shown in Figure 3, each curve becomes the median line of results. The assumption of normal distribution, although not rigidly true, may be considered valid for these tests. Thus, each curve shows that 50 per cent of the time the results of M.P.N. determination will be less than the values noted on the curves for each contact period.

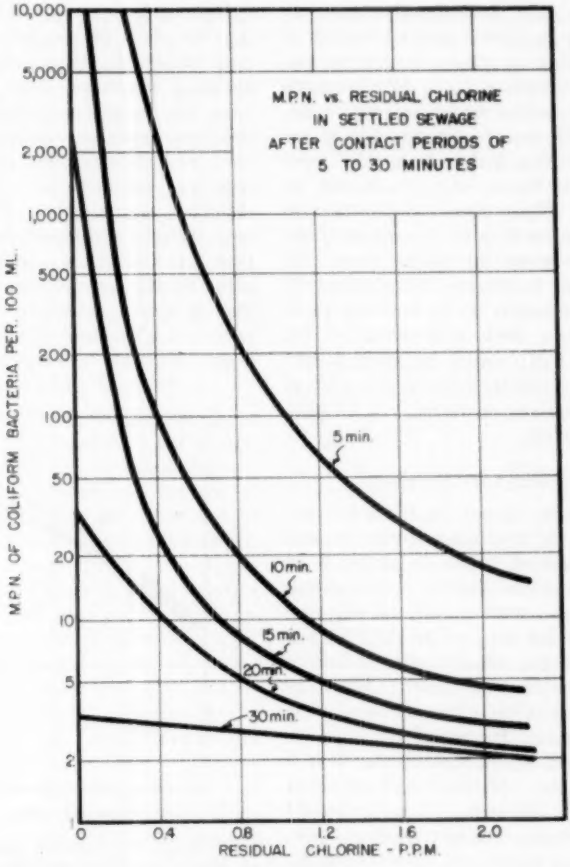


**FIGURE 3.**

Specifically, the curve in Figure 2 shows that if a chlorine residual of 0.2 p.p.m. exists after a 15-min. contact period, the probabilities are that the chlorinated primary effluent at Ridgewood would have less than 100 coliform organisms per 100 ml. of sewage 50 per cent of the time. This is the frequency basis on which pollution abatement control agencies establish their standards. In other words, operators are given a 50–50 chance of meeting specified bacteriological standards. These data and resulting curves show the chlorine residuals and contact times necessary for a certain sewage effluent to meet these standards.

Another statistical method worthy of consideration is that employing the standard deviation, $\sigma_y$, to determine the range of results which might be expected with certain frequencies of occurrence. The dotted lines in Figure 2 show the limits of $\sigma_y$ each side of the curve. These lines indicate that 68 per cent of the time the values obtained will lie between the dotted lines. It is apparent in Figure 1 that most of the plotted points do lie between these lines. Thus, with a residual of 0.4 p.p.m., M.P.N. values between 4 and 500 will be obtained in 68 per cent of the observations made with a 15-min. contact period.

## Significance of Results

The results shown in Figure 3 are significant to designing engineers and plant operators. The importance of contact time is clearly emphasized. For instance, with a residual chlorine content of 0.4 p.p.m., the M.P.N. per 100 ml. of the effluent after a 5-min. contact period was 2,000. After 10 min. it was 100; after 15 min., 30; after 20 min., 10; after 30 min., 3. The greatest kill comes in the first 5 min., but the additional kill obtained during the following 5 min. would make a 10-min. contact period desirable in most instances. Whether additional contact time is necessary can be determined by an economic analysis of the cost of contact tank construction versus the capitalized cost of chlorine to achieve an effluent of similar quality.

Before such an analysis can be undertaken, it is necessary to determine the chlorine dosage required to achieve the desired residual after specified contact periods. Figure 4 shows the relationship between chlorine dosages and residuals after contact periods of 5, 15, and 30 min. These curves apply to the primary settled sewage at Ridgewood, N. J., and are based on results obtained during the course of the experiments reported in this paper.

Reference is made to Figure 1 showing the effect of contact time on chlorine residuals. It is evident that the residual decreases very slowly with time, the reason being that the residual chlorine exists as combined available chlorine—chloramines and organic chlorine compounds, which release chlorine very slowly. Thus, it takes only a slight additional dosage of chlorine to maintain a certain residual after 30 min., as compared with 5 min. For example, referring to Figure 4, to obtain a residual of 0.4 p.p.m. after 5 min. requires a dosage of 6.4 p.p.m.,

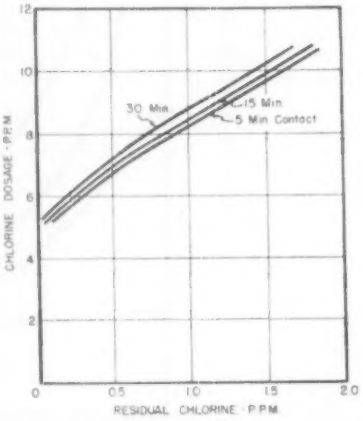


FIGURE 4.—Chlorine dosages required to obtain specified residuals after various contact periods with settled sewage.

**TABLE V.—Effect of Contact Time on Residual Chlorine and M.P.N. After Dosage with 6 p.p.m. of Chlorine**

| Contact Time (Min.) | 5 | 15 | 30 |
|---|---|---|---|
| Orthotolidine Residual (p.p.m.) | 0.30 | 0.25 | 0.20 |
| M.P.N. per 100 ml. | 8,000 | 80 | 3 |

whereas the same residual after 30 min. would require a dosage of 6.9 p.p.m.

Therefore, chlorine dosage is not as significant a factor as contact time in achieving greater kills of coliform bacteria. Cross-reference to Figures 3 and 4 indicate that 6.4 p.p.m. of applied chlorine will result in a M.P.N. of 2,000 after 5 min., whereas 6.9 p.p.m. will result in a M.P.N. of 3 after 30 min., both dosages giving the same residual of 0.4 p.p.m. after their respective contact periods.

To determine the effect of equal dosages and various contact periods, consider the addition of 6 p.p.m. of chlorine to the primary settled effluent at Ridgewood. Using Figures 3 and 4 in conjunction, the expected results will be as shown in Table V.

## Practical Applications

The methods developed in this paper have a direct application to the design and operation of chlorination systems where sewage characteristics are known and chlorination to an orthotolidine residual will be practiced. Although twelve samples were used in the above work, previous studies (1) have shown that ten samples will suffice. Therefore, chlorination tests should be performed on ten samples of sewage taken from the point where chlorine will be applied in the plant. These samples should be taken on ten different days and at different times of day. Chlorine dosages should range from 100 to 200 per cent of the standard 10-min. chlorine demand, preferably in four groups of 100, 133, 167, and 200 per cent of the demand. Contact periods should be chosen in accordance with the average period in the existing plant, the period required by the state department of health, or the range of periods being considered by the designing engineer.

By interpreting the tests as outlined herein, it will be possible to determine the chlorine dosage and chlorine residual necessary to achieve the desired M.P.N. of coliform bacteria in the effluent. Furthermore, the results will enable the designing engineer to evaluate the cost of constructing chlorine contact chambers of various sizes against the capitalized cost of chlorine at each contact period.

If enough tests were performed in various plants of any particular state, it should be possible to correlate the data and establish a rational basis for the design of chlorine contact chambers. The need for this rational basis of design of contact chambers was brought out by Faber (3) in his survey of the heterogeneous chlorination regulations of state departments of health throughout the country.

## Summary

Chlorination experiments were performed on the primary clarifier effluent from the sewage treatment plant at Ridgewood, N. J. Samples were taken on twelve separate days at dosages equivalent to 100, 133, 167, and 200 per cent of the standard chlorine demand of each day's sewage. Chlorine residual tests, as measured by orthotolidine, and M.P.N. determinations of coliform bacteria were made after contact periods of 5, 10, 15, 20, and 30 min.

The results of the tests for each contact period were plotted on semi-logarithmic paper and analyzed by statistical methods to determine the equation which would best express the relationship between M.P.N.'s and chlorine residuals. It was found that a reciprocal curvilinear function was the curve of best fit when all contact periods were considered. Standard deviations and

coefficients of correlation could be determined for each curve.

Using the equations, curves were plotted for each contact period. These curves showed the value below which the M.P.N. of coliform bacteria could be expected to fall 50 per cent of the time at each chlorine residual. Relationships of M.P.N's, residuals, and contact times were presented on one graph. Chlorine dosages necessary to achieve certain residuals were also obtained during the course of the experiments.

Similar graphs can be developed at any sewage treatment plant by running the above tests. The results can be used as a guide to chlorine dosage in the control of the M.P.N. of coliform bacteria in sewage effluents and in the establishment of rational bases for the design of chlorine contact chambers.

## Acknowledgments

This work was performed in the Lewis V. Carpenter Sanitary Engineering Research Laboratory, College of Engineering, New York University, under a research fellowship sponsored by the Wallace and Tiernan Company. A. E. Griffin of that company rendered valuable advice during the course of the research. Grateful acknowledgment is given for the services performed by John W. Hood, superintendent of the Ridgewood, N. J., sewage treatment plant.

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## DIRECTORY OF WISCONSIN ENGINEERS

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# SEPTIC TANKS: DESIGN AND PERFORMANCE*

By Harvey F. Ludwig

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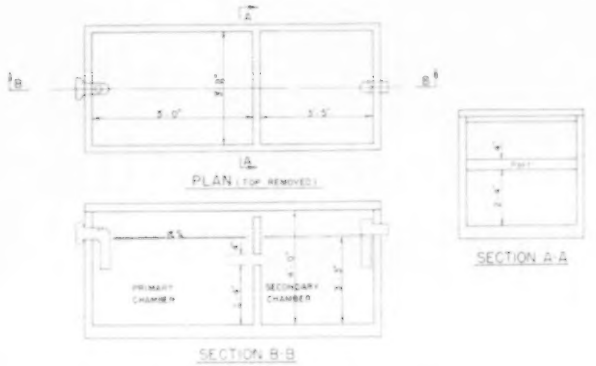
In earlier discussions (1) (2), studies have been described in which field tests were made to compare the performances of septic tanks having different proportions of length to width. Specifically, it was attempted to determine whether large septic tanks formed by placing in series a number of smaller ones is good practice; that is, does the larger tank thus formed, with its higher ratio of length to width, produce as satisfactory an effluent as a single tank of conventional proportions, when both are loaded at their rated capacity? The question arises because most health departments throughout the United States require that the length-width ratio for septic tanks not exceed 3:1.

This question is of much practical significance because of the economy which may be effected by constructing large septic tanks simply by placing in series a number of precast single-tank units. The single units are fabricated in such a way that their end walls and intermediate baffle walls may be left out. The elongated tank is made up with only a single baffle wall, and hence is a two-compartment tank of slender proportions. Over the last 20 years several hundred of these elongated tanks have been installed at various places in California, principally at schools, at costs much lower than the costs of casting specially-designed conventional-type rectangular reinforced concrete tanks. For example, a 5,000-gal. tank designed according to the usual health department regulations, having a liquid depth of 5.0 ft. and a length-width ratio of 3:1, would be 20.1 ft. long and 6.7 ft. wide. To construct such a tank requires careful excavation, double-forming, and reinforcing specially designed and placed. The same capacity may be obtained more economically by placing in series seven of the precast units, each of which has a liquid capacity of 750 gal.

## Comparative Field Tests

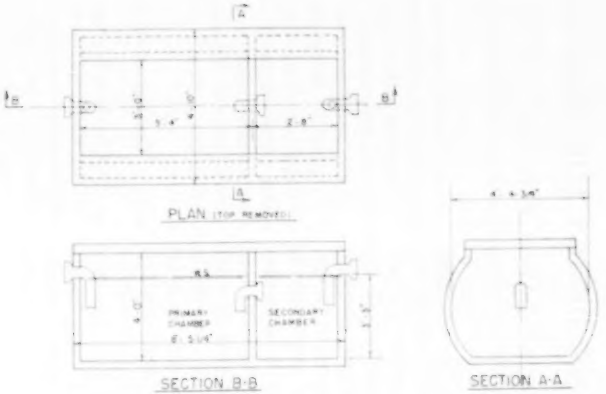
This successful record of experience led to the establishment of an actual field comparison under controlled conditions of the results effected by a conventional-type or "standard" rectangular tank of 800-gal. liquid capacity, having a liquid depth of 4.0 ft. and a length-width ratio of 2.5:1, and by an elongated-type or battery tank of 5,250-gal. capacity made up of seven of the precast units. The two tanks (Figure 1) employed for the study have been tested under identical conditions for a period of 15 months, for both uniform flow and surge flow conditions. In these tests the exact contents of each tank was displaced each day, over a 12-hr. period, six days each week. For the uniform flow tests, a steady flow was maintained over the 12-hr. period. The surge tests were conducted by charging the tanks six times daily with batches of sewage each equal to one-sixth of the tank capacity. Each batch was added over a period of approximately 7 min. The sewage employed for the tests was sanitary sewage taken from the Monrovia, Calif., municipal outfall, and consid-

* Presented at Twenty-second Annual Meeting, Arizona Sewage and Water Works Association; Prescott, Ariz.; April 1–3, 1949.




RECTANGULAR SEPTIC TANK (BAKER TYPE)

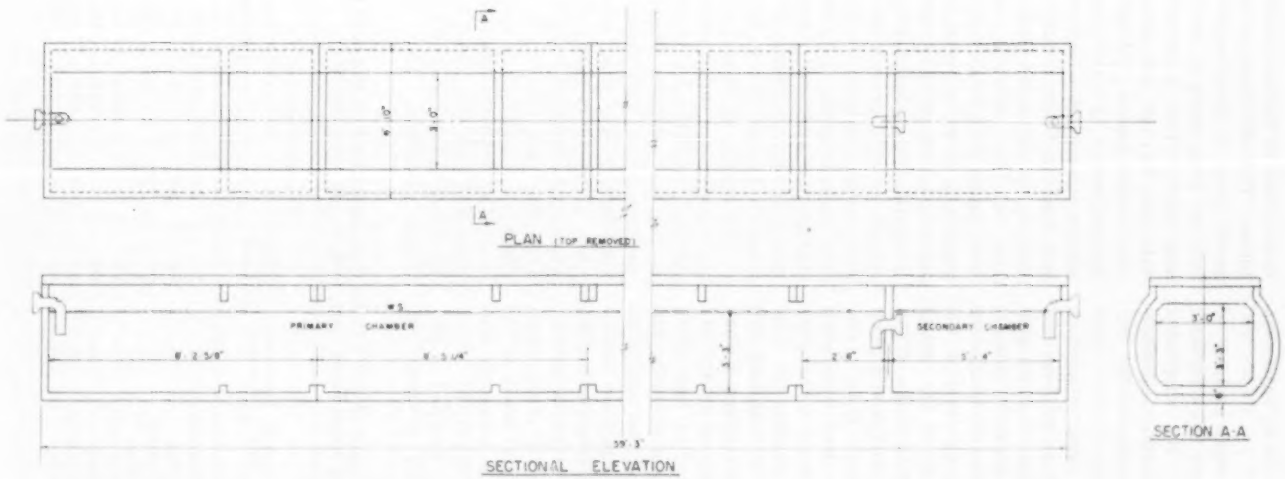
CAPACITY = 800 Gallons (liquid)
Length Width ratio = 2.7 : 1




HYGI-SEPT SEPTIC TANK

CAPACITY = 750 Gallons (liquid)
Length Width ratio = 2 : 1

NOTE
This tank not used in Test Program
Shown to illustrate single Hygi Sept tank installation




SEVEN UNIT HYGI-SEPT BATTERY INSTALLATION

CAPACITY = 5250 Gallons (liquid)
Length: Width ratio = 4.5 : 1

**FIGURE 1.—Septic tank installations employed in test program.**

ered to be typical Southern California domestic sewage.

Composite daily sewage samples of the influent and effluent flows for both tanks were analyzed for suspended solids and settleable solids, and sometimes for B.O.D. Results for the first 8 months of the study (1) (2) show that the elongated tank effected a greater efficiency for both uniform and surge flows. In the first 8-month program the only sludge materials present in the tanks were those accumulating from the sewage passing through the tanks, and at the end of the initial period there was in both tanks only a few inches of bottom sludge and practically no surface mat. Both tanks, therefore, may have been operating under optimum conditions. The question then was raised whether the relative performances of the standard and elongated tanks might be altered when an appreciable quantity of sludge had been collected, as in this case there might be some carry-over of sludge materials in the elongated tank due to its relatively higher displacement velocities. Accordingly, in December, 1948, there was added to both tanks in identical fashion an amount of sludge equal to one-third of the liquid depth of the tanks. This amount is commonly considered the sludge depth at which septic tanks should be pumped to prevent rapid falling off of tank efficiency due to further sludge accumulation. The added sludge was obtained partly from a school septic tank that had not been pumped for three years, and partly from a municipal septic tank that had not been pumped for an even longer period. In both instances approximately 13 per cent of the sludge volume was added to the standard tank and the remaining 87 per cent to the elongated tank, in proportion to their relative volumes. In both tanks the sludge was distributed uniformly over the entire tank length, including both primary and secondary compartments. After allowing a 1-month period for equilibrium conditions to be attained, the test program was re-commenced. Uniform flow conditions were employed during January and February, and surge flows over the 5-month period March through July.

The results of these later tests, together with the earlier data, are summarized in Table I. In the presence of the heavy bottom sludge layer the performance of both septic tanks was considerably less than in the earlier tests. Periodic bubbling of the sludge masses was observed in both tanks, and this sometimes resulted in heavy discharges of suspended matter. However, the relative superiority of the elongated tank was found to be greatly increased under the condition of heavy sludge loadings. The increase in

**TABLE I.—Summary of Test Data for Comparative Study of Elongated and Standard Septic Tanks (July, 1948, to July, 1949, Inclusive)**

| Type of Solids | Sludge Added | Type of Flow | No. Days Operation | No. Days Sampled and Tested | Influent Concentration[1] | | % Removal[1] | |
|---|---|---|---|---|---|---|---|---|
| | | | | | (p.p.m.) | (ml./L.) | Elongated Tank | Standard Tank |
| Suspended | No | Uniform | 75 | 75 | 247 | — | 89 | 80 |
| Suspended | No | Surge | 48 | 30 | 333 | — | 94 | 84 |
| Suspended | Yes | Uniform | 49 | 40 | 620 | — | 78 | 65 |
| Suspended | Yes | Surge | 128 | 82 | 88 | — | 32 | 15½ |
| Settleable | No | Uniform | 75 | 75 | — | 10.3 | 96 | 91 |
| Settleable | No | Surge | 48 | 30 | — | 13.8 | 98½ | 94½ |
| Settleable | Yes | Uniform | 49 | 40 | — | 27.0 | 91½ | 81½ |
| Settleable | Yes | Surge | 128 | 82 | — | 2.9 | 66½ | 35 |

[1] Average.

superiority of the elongated tank is attributed to its much greater capacity for absorbing surge flows, as indicated by the number of days when the tank effluent contained more settleable solids than the influent. Out of the total number of test days sampled, namely 82, this condition of excessive discharge occurred 31 times with the standard tank, and only 5 times with the elongated tank. Another indication is the comparison of total mass of solids received and discharged by the tanks during the 82 days sampled. The total volume of settleable solids received by the standard tank was 192 gal., and the total volume discharged was 255 gal. The corresponding figures for the elongated tank were 1,260 gal. received and 432 gal. discharged. Actually, therefore, the respective over-all efficiency for removing settleable solids was plus 66 per cent for the elongated tank and minus 33 per cent for the standard tank. (These values are different from the efficiencies shown in Table I because in computing the values in Table I a condition of excessive discharge on any day was considered as zero efficiency for that day, rather than as a negative efficiency.) In summary, it may be concluded that the more critical the operating conditions for the tanks, the better has been the relative performance of the elongated tank.

These results are believed to be consistent with theoretical considerations. Actually a septic tank provides three distinct functions: (1) primary clarification, to separate out settleable and floatable materials; (2) storage and digestion of these separated materials; and (3) bioseptic treatment of the non-settleable suspended particles, through contact with a septic environment, to change the character of these particles from a gelatinous nature to a non-gelatinous nature, so that the effluent discharged from the tank may be filtered relatively easily through the soil without clogging of the soil pores. With respect to the first function, the performance of the elongated tank should be better because the higher ratio of length to width minimizes short circuiting, particularly under conditions of surge flow. Although this higher ratio does result in proportionately higher average lineal displacement velocities, these velocities are so small that they are believed to be negligible, even in elongated tanks made up of as many as 15 units. The second and third functions probably are little affected by the length-width ratio, but with respect to the third function septic tank performance should be better for shallower depths. With a shallower depth, the horizontal areas of bottom sludge and surface mat which are exposed to the sewage flow are proportionately greater; thus a greater contact area and a greater degree of bioseptic treatment should be provided. Actually the precast units utilized for the test have a liquid depth of only 39 in., whereas the standard tank has a depth of 48 in., this being the minimum depth acceptable by most health department regulations.

## Conclusions

1. Comparison of the performance of a 5,250-gal. elongated battery-type septic tank with an 800-gal. standard tank, with both operating at their rated capacities, showed a superior performance by the elongated tank, under conditions of both uniform and surge flows, and both in the presence and absence of heavy sludge accumulations. The relative superiority is greater in the presence of heavy sludge loadings.

2. Septic tanks with length-width ratios higher than the 3:1 ratio commonly specified, and of depths shallower than the 48-in. minimum commonly specified, may effect a better degree of treatment than do standard tanks.

3. Limiting values for the length-

width ratio and for depths are not known, but a ratio as high as 20 : 1 and a depth as shallow as 30 in. are believed to be satisfactory.

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## ILLINOIS STRENGTHENS STATE POLLUTION CONTROL AUTHORITY

Even though the Illinois Sanitary Water Board Law has, for a number of years, been considered one of the most effective of state pollution control authorities, the Illinois legislature further strengthened the authority of the Board in the 1949 legislative session.

The amendments, in addition to the pollution abatement powers already assigned the Board, included new authority to prevent pollution by giving the Board jurisdiction over "all substances and materials which pollute, threaten to pollute, or tend to pollute" surface and underground waters. In the recent changes, the Sanitary Water Board was given the right to adopt and enforce rules and regulations for the submission of data relative to changes or extensions in sewerage systems, for the preparation and submission of operation reports (not only from municipalities, but also from industries), and for setting up qualifications and requiring certification of the technical competency of operation personnel of sewerage systems.

One of the important changes involved violations. The amended authority permits action in the Circuit or Superior Court by means of mandatory or prohibitive injunctions "whenever the Board shall be of the opinion that any person or persons, individual, public or private corporation, political subdivision, government agency, municipality, public or private institutions, industry, co-partnership, association, firm, trust, estate, or any other entity whatsoever is failing or omitting or about to fail or omit to do anything required of it by law, or by any order, decision, rule, regulation, direction or requirement of the Board, issued or made under authority of this Act, or is doing anything or about to do anything or permitting anything or about to permit anything to be done, contrary to or in violation of the law or any order, rule, regulation, direction or requirement of the Board, issued or made under authority of this act."

Whenever complaint of pollution of surface or underground waters shall be filed with the Board, the Act makes it mandatory that the Board investigate and if pollution is found makes it the duty of the Board to proceed under the Act.

Penalties under the amended Act provide for a fine of $100 a day or by imprisonment for 30 days, or both, with each day's continuance of such violation or failure constituting a separate offense.

The amended Act was passed unanimously by both houses of the legislature and was co-sponsored by representatives from both major political parties.

# Industrial Wastes

## BIOLOGICAL TREATMENT OF SPENT LIQUOR FROM THE SULFITE PULPING PROCESS*

By J. M. Holderby and Averill J. Wiley

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Feasible methods for treating spent liquor from the sulfite pulping industry have been very difficult to develop and even today few processes can be considered successful on more than a relatively small scale. The stream pollution aspects of the problem have been recognized as serious since the first commercial exploitation of the sulfite pulping process about 70 years ago. Agitation against disposal by dilution has grown with the years, accented by costly damage suits and many proposals for restrictive legislation.

Quite aside from the pollution problem inherent in the sulfite pulping process there is an economic problem of growing importance which is concerned with the portion of the wood that goes to waste. The magnitude of the problem can be realized when it is considered that dry wood costing the pulp mill as much as $20 per ton yields only 950 lb. of cellulose pulp. With the exception of minor losses of volatiles in the blow off and relief gases, the remaining 1,050 lb. of wood substance are dissolved in the cooking liquor and are wasted to the streams. In these discarded wood solids are some 750 lb. of lignin (the cementing substance which binds the cellulose fibers into wood substance), 250 lb. of wood sugars, and perhaps 50 lb. of resins and various other wood substances that may be grouped under the head of extractives. These organic substances, were they easy to recover, would be quite valuable in various ways, not the least of which, in these days of high fuel costs, would be as a source of heat capable of supplying most, if not all, of the steam requirements of the pulp mill.

It is not surprising to find many critics who fail to understand why a pollution problem and an economic loss of this order could persist over a period of so many years.

The answer lies in three principal attributes characteristic of sulfite waste liquor (SWL):

1. The great dilution of the organic matter.
2. The corrosive properties of the sulfurous and acetic acid content.
3. The ash- and scale-forming properties, which stem from the calcium base cooking acid used in the process.

All three of these factors have served to deter development of practical methods of treating the spent liquor; but the first, concerned with the large volumes to be handled, has perhaps proved the most serious single handicap. For the average 100-ton sulfite pulp mill, which uses 210 tons of pulpwood, the normal waste volume totals around 5 m.g.d., and includes 110 tons of wood solids in solution. Of this amount, it is pos-

* Presented at 22nd Annual Convention, Central States Sewage Works Association; Chicago, Ill.; June 17–18, 1949.

sible to segregate some 0.3 m.g.d. of relatively strong liquor containing up to 90 per cent, or about 100 tons, of the dissolved solids. Even this fraction, running around 10 per cent solids content, presents a serious handling problem. For use with existing, accepted methods of utilization, the concentration has been too low to permit recovery of values competitive with other cheap sources of heat, of sugar, etc. On the other hand, the waste has been found to be too strong to permit economic disposal by standard biological methods of waste treatment. The remaining 4.7 m.g.d. is composed of dilute wash water in which about 10 tons of wood solids are dissolved. The population equivalent of the combined wastes is about 300,000.

The research group the writers represent was organized in 1939, with a membership of 13 Wisconsin and Michigan pulp mills, and culminated the recognition of certain facts:

1. No process was known that was capable of economically treating and disposing of SWL.
2. Few, if any, pulp mills could hope to finance alone the laboratory research, pilot-plant development, and final commercial-scale testing of new processes.

First efforts of the new organization were directed toward a thorough survey of the then existing methods and ideas. Of these, some 44 different ones have been studied to date, ranging through the fields of physical, chemical, and biological treatment. However, because more than 80 per cent of the 5-day B.O.D. accrues from the content of wood sugars and their derivatives present in SWL, much emphasis in terms of research funds and of manpower has been directed toward biological methods of treatment to remove or destroy these compounds.

This paper outlines the conclusions drawn from the first 10 years of work conducted by the Sulphite Pulp Manufacturers' Research League, Inc., on biological methods of disposing of SWL. Results of certain of these research projects now appear very promising; but even the commercial-size yeast plant, after the first 6 months of operation, remains in an experimental status, due to high costs inherent in any process for handling SWL and the need for recovery of firm values if the process is to be economically practical.

## Activated Sludge Treatment

At the time the research program was first being organized, the work on laboratory evaluation of activated sludge treatment of SWL, being carried out by Sawyer (1) (2) under the auspices of the Wisconsin Alumni Research Foundation at the University of Wisconsin, was closely followed. Sawyer reported B.O.D. removals as high as 95 per cent in treating dilute SWL by this method, and the review was designed to explore the feasibility of setting up pilot-scale trials. However, the laboratory experiments ultimately showed certain difficulties concerned with settling sludges and with foaming problems to be so serious at practical load levels as to preclude further work at that time. Sawyer found the calcium content of the waste liquor prone to transfer to the sludge, increasing its density and causing settling out, even under the most intensive aeration. The lignosulfonic acid content of SWL is surface active and leads to intensive foaming properties, which have seriously interfered with conventional aeration processes wherever tried. In the activated sludge process, foaming was found to lift the sludge, and even to carry it from the reaction chamber unless special measures were taken to break the foam. Chemical defoaming agents, such as sulfonated oils, were effective in destroying foam, but had to be fed continuously in such quantity as to be uneconomic.

Although no encouragement was given to study the activated sludge process on a large scale because of the low levels of loading indicated as feasible and due to the aforementioned difficulties, still this process does seem to be conditionally capable of removing substantially the whole of the recognized stream pollution characteristics of this waste liquor. No alternative methods of biological treatment so far studied have shown promise of removing as much as 95 per cent of the B.O.D.; nevertheless, this goal is set. Apparently, the diverse flora of a balanced activated sludge contains individual organisms which in the aggregate can attack and consume nearly all of the wood sugars and the sugar breakdown products responsible for the 5-day B.O.D. of SWL.

### Trickling Filter Treatment

Study of application of the trickling filter process to treatment of SWL was carried out as a major project continuously during the first 5 years of the research work, and was followed by another 2 years of concluding studies conducted in cooperation with the National Council for Stream Improvement. Initial work in the laboratory and with 30-in. pilot filters (Figure 1) has been reported (3). Pollution removal in terms of B.O.D. was shown to run as high as 75 per cent on throughout, with loadings indicated as much more promising than for activated sludge. Subsequently, a 15-ft. pilot filter (Figure 2) was constructed, but this larger unit served to point out many problems not previously recognized, and which have since resulted in an unfavorable economic picture.

These later studies have not been completely detailed and summarized for publication, but the conclusions on the trickling filter process may be outlined briefly as follows:

1. Raw, untreated SWL can be treated on a trickling filter with B.O.D. removals averaging 65 per cent, as based on the waste liquor actually processed, and possibly running as high as 75 per cent when conditions are so controlled as to be particularly favorable.

2. Favorable conditions, however, are apt to be very difficult to maintain in continuous operation because:

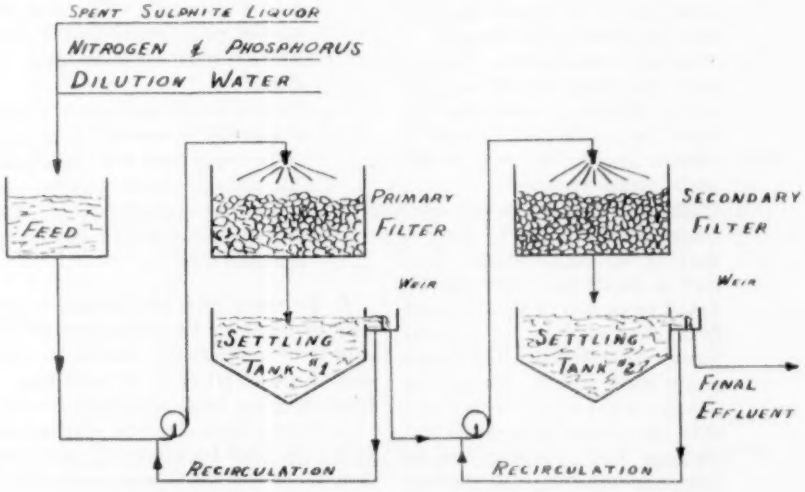


FIGURE 1.—Flow sheet for 30-in. trickling filter pilot plant.

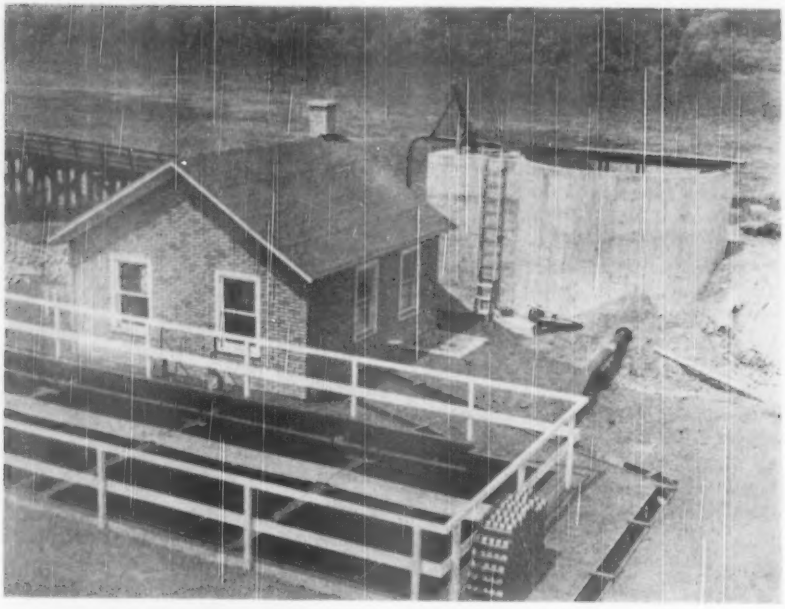

FIGURE 2.—Pilot plant using 15-ft. diameter trickling filter.

*a.* Efficient aeration is hindered by heavy growth on the filter, with resultant ponding problems, especially where small media are used. Rock grading not less than 4 in. in the largest diameter has been best in this respect.

*b.* Seasonal temperature changes have important effects on operating efficiency, and may be more than ordinarily difficult to handle due to the size of the installations required.

*c.* High acidity results in low operating pH and leads to production of a characteristic flora high in molds and yeast and deficient or devoid of the balanced flora characteristic of normal filters. In particular, the higher plant and animal forms are missing in the biota. This probably contributes to periodic unloadings and resultant loss in operating efficiency for periods of a week or 10 days each time.

3. Very large and expensive installations would be required:

*a.* Approximately 8 acres of filter area 6 ft. deep would be required to handle SWL from 100 tons of pulp production daily.

*b.* Filter media must be acid resistant.

*c.* Filters, tanks, and other vessels ordinarily constructed of concrete would have to be tile lined.

*d.* All piping, valves, pumps, and operating controls would have to be fabricated from 316 stainless steel alloy.

4. Nitrogen and phosphorus nutrients required by the process would be expensive and there would be but small hope of recovery of more than a fraction in the form of saleable sludge.

5. Dosing rates must be maintained at a high level by means of recirculation, for which the power consumption for pumping would be high.

Active research on the trickling filter process has been terminated by the organization as a result of this unfavorable picture, but the equipment is being maintained in stand-by condition for possible later study of special problems.

### Contact Aeration

Claims advanced for the Hays process of contact aeration seemed to offer possibilities for overcoming certain of the disadvantages demonstrated in the activated sludge and trickling filter treatment of SWL. Therefore, a project was set up late in 1942 for the purpose of evaluating that process and work was continued for a period of some 2 years. The flow sheet for this equipment is shown in Figure 3.

The contact aerator carried much heavier loadings than any process studied up to that time, and maintained B.O.D. removals running from 70 to 75 per cent. The chief limitation on the process seemed to be concerned with inability to provide sufficient air. As the loading and the concentration of the spent liquor increased, foaming in the aerator became unmanageable and in this respect resembled the activated sludge experiments by Sawyer. It also was found very difficult to introduce air efficiently by the equipment then available. Pipe grids corroded and plugged, and diffuser stones became coated with inorganic precipitates.

Difficulties with the contact aeration process were primarily mechanical in nature and the results might have been improved upon had time been available to study and develop new methods of aeration and of foam control. Under the pressure of wartime manpower problems, this phase of the research program had to be terminated. Further contact aeration studies have since been deferred for possible future development work.

### Anaerobic Methane Fermentation of SWL

Simultaneously with the aerobic biological methods of treatment above reported, analogous studies were conducted on the anaerobic methane fermentation of SWL over a 3-year period extending to 1944. Interest chiefly centered in evaluating this process in terms of the comparative

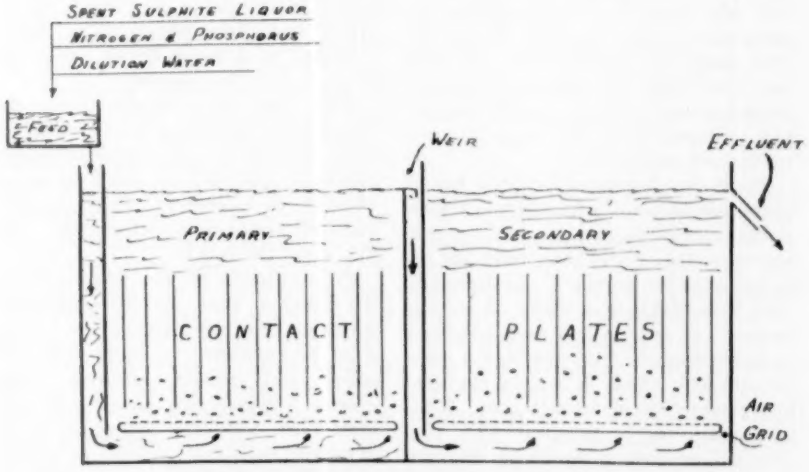


FIGURE 3.—Contact aeration treatment of SWL.

ease with which a product of value could be recovered and used to pay at least a portion of the processing costs, with simultaneous reduction in the pollution properties of the spent liquor so treated. Methane gas is a highly efficient fuel, universally marketable, and can probably be recovered from the treatment process proper more easily than any other product so far proposed in the studies.

The chief disadvantage of the methane fermentation has been the low rates of fermentation, extending into holding times of a week or more. Significant reductions in the retention time were found to be possible in the course of the studies, but, as with the activated sludge and contact aeration processes, it was found necessary to extend priority of research time to other processes of more immediate promise and worth.

## Yeast Production from SWL

Early in the war years, reports began to reach this country of the remarkable success of Fink, Lechner, and Just (4) with cultivation of the pentose fermenting yeast, *Torulopsis utilis*, in SWL. Preliminary studies in the laboratory confirmed these results and also showed very promising degrees of pollution removal. With wartime shortages emphasizing the food and feed value of yeast as sources of vitamins and proteins, nearly the entire research effort was soon devoted to this one project.

From the beginning it was found necessary to modify known yeast production methods and to develop new unit processes to fit the particular requirements for growth of the organism with high efficiency in SWL. A certain measure of success has been attained in these respects; but, although a commercial-scale plant is now in continuous production at Rhinelander, Wis., it is still deeply involved with mechanical processing problems not yet developed satisfactorily. There is good reason to hope that these problems will be resolved in due time, but as yet the plant is in an experimental status and can hardly be expected to be removed from that category within the next 6 months, and possibly longer.

The yeast process, as outlined in Figure 4, includes liquor collection from the blow pits, screening to remove entrained pulp fiber, and storage of raw spent liquor in sufficient volume to permit continuous operation of the yeast plant from liquor produced on a batch basis in the pulp mill. Certain substances in the spent liquor must be removed in a pretreatment step in order to permit yeast growth. The treated sugar-containing liquor then passes continuously at controlled flow rates into the large fermentor, along with yeast nutrients and large quantities of air.

The growth process is very rapid and involves a holding time of only a few hours. Conditions are so controlled as to prevent the formation of alcohol and to favor conversion of as much sugar as possible to yeast-cell substance. The yeast-containing "beer" then passes to special centrifuges, which separate the yeast from the liquor. The yeast is washed with well water in succeeding centrifuge operations, and then passes as a heavy "cream" to a drum dryer, which delivers it as a dry powder.

The yeast-free effluent from the centrifuges has 90 to 95 per cent of both the hexose and pentose sugars removed, and also is freed in somewhat lesser degree of other organics, such as acetic acid, which also contribute to the B.O.D.

Substantially all the equipment in the process must be of high-grade corrosion-resistant material. Nutrients must be furnished to supplement the sugar and permit effective yeast growth. Steam and power costs are high. At best, the operation is an expensive one; and in order to be economically practical, values must be

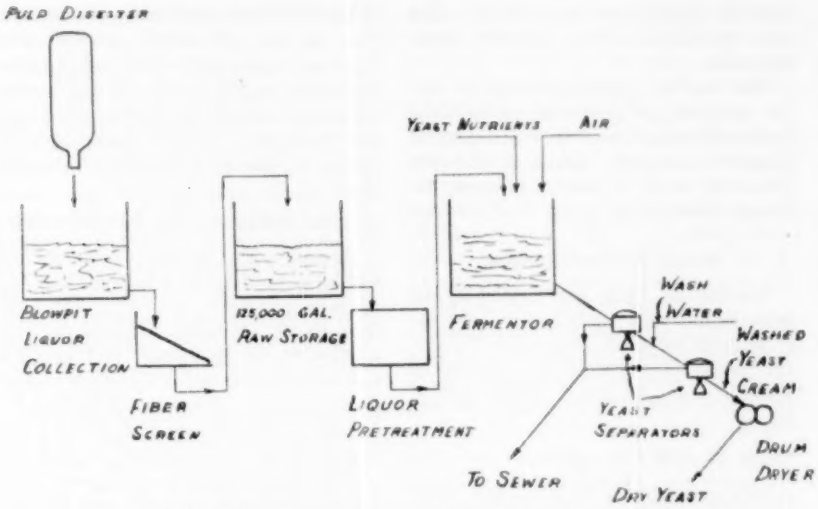


FIGURE 4.—Flow sheet for yeast production from SWL.

recovered which will at least partially offset the cost of treatment. Opportunity for such recovery is presented by the dried yeast.

The *Saccharomyces* yeasts common to the brewing, distilling, and baking industries have long been recognized as superior natural sources of the vitamin B complex. They are also rich sources of protein, amino acids, enzymes, and other products. In addition to their direct food use in the form of leavening agents, they have been widely used as supplements in both animal and human foods, and as raw materials for various pharmaceutical products. Studies initiated as early as 1916 have proven *Torulopsis utilis* to possess nutritional values and characteristics quite similar to *Saccharomyces* yeasts. In the present process, *Torula* is produced from sterile wort by a substantially pure culture procedure. It is, therefore, reasonable to assume that it will be acceptable for use in any field for which it may otherwise be suitable.

Accordingly, steps have been taken to thoroughly evaluate the potential market for the material and thus determine the ultimate practicability of the process. Indications are that the bulk of the demand will be in the poultry food field, but other promising outlets are definitely in sight. It is just possible that the economic evaluation of the process will lag behind its technical demonstration by a considerable period.

Equally as important as, and closely tied up with, the market survey is the determination of ultimate production costs. Such determination remains as one of the primary objectives of the first year of production.

The first months have shown many operational problems requiring refinement. Some equipment which did not scale up well between pilot and commercial stages has had to be replaced. Large amounts of heat are produced as a result of yeast growth, and this must be dissipated. Cooling water problems may become critical during summer months. Yeast separators are designed to be operated at highest efficiency under one set of conditions, but it has been necessary to deal with

variable flows and conditions. The same problems affect efficient dryer operation.

The end of these problems is not yet in sight, let alone solved, and the consequent shutdowns for experimental research adversely affect production costs—so much so as to prevent accurate determination up to this time.

## Other Process Studies

Insofar as data are available, an attempt has been made to keep abreast of studies on other promising biological processes reported by others as suitable for treating spent sulfite liquor.

### *Ethyl Alcohol Production*

Two commercial plants have been producing ethyl alcohol from SWL on this continent, and another large plant is reported to have been under construction in Canada during the past 18 months. The two operating units, one at Bellingham, Wash. (5), and the other at Thorold, Ont. (6), have benefited from the period of wartime price structures, ranging to 80¢ per gal. for 95-per cent alcohol. More recently, the economics of production from these plants have been changed by a marked decrease in the price of alcohol to the present level of around 20¢ per gal. At this price, alcohol production is considered to be marginal and may not be able to stay out of the red, even in the case of these two large mills, each of which produces more than 200 tons of pulp per day. With the average size mill (capacity 80 to 110 tons daily) the economics of alcohol production have not appeared promising, even when alcohol was being priced at high levels.

Alcohol processing of SWL has not been shown capable of more than nominal degrees of pollution reduction. Thorough studies are lacking, but all results so far reported indicated 5-day B.O.D. removals of only 40 to 45 per cent. This is due to selective action of the anaerobic ethyl alcohol fermentation on the six carbon sugars only. Pentose sugars and certain other sugar products in SWL, all of which contribute substantially to the B.O.D., are not attacked or removed from the spent liquor by the ethyl alcohol fermentation.

### *Acetone-Butyl Alcohol Fermentation*

Acetone-butyl alcohol fermentation has been studied as a possible method of treating SWL (7) (8), but such data as are available indicate the economics to be no better, and perhaps not so favorable as for the ethyl alcohol fermentation. The market outlets for normal butyl alcohol and for acetone definitely do not warrant capital expenditures for new large fermentation plants producing at high cost against actual or potential low-cost synthetic sources.

Pollution removal aspects of the acetone-butyl alcohol fermentation are not completely evaluated. They are indicated, however, to be at least as good as with the ethyl fermentation and probably would be better where pentose sugars are utilized.

### *Lactic Acid Production*

Leonard, *et al.* (9) have reported favorably on possibilities for producing lactic acid from sulfite liquor. Because this fermentation is capable of utilizing pentose sugars, and also because lactic acid recovery may involve evaporation, the potentialities for efficient removal of B.O.D. may be good. Evaluations so far are believed to have been limited to laboratory scale.

### *Foam Phase Processing*

Recently, Logan and Heukelekian (10) have reported results of interesting studies, wherein mixed cultures and also pure yeast cultures were cultivated in spent sulfite liquor foam. As excellent B.O.D. removals were found to take place in 24 hr. or less, their work should merit further investigation.

## Comparative Evaluation of Biological Methods

A summary of available data comparing the B.O.D. removals and loadings reported for the various processes here discussed is given in Table I. In terms of loading, the methane fermentation and the activated sludge disposal methods rank lowest, with capacities of around 1.5 to 1.7 lb. of B.O.D. per cu. yd. of tank volume per day. By contrast, the ethyl alcohol and yeast production processes have been found capable of handling from 60 lb. to more than 100 lb. of B.O.D. per cu. yd. per day.

The efficiencies of these processes in terms of removal of B.O.D. are shown in the second column in terms of the highest known removal reported for each process. The last column indicates the practical range of removals to be expected from large-scale trials with spent liquor. The highest known degree of removals by any biological process treating SWL is the carefully established value of 95 per cent reported by Sawyer (1). On the other extreme, the ethyl alcohol process is now generally recognized as being unable to effect reductions much in excess of 55 per cent. Those processes studied in detail in the League's laboratories have all shown potentials in excess of 80 per cent B.O.D. removal.

**TABLE I.—Comparison of Process Efficiencies for Various Methods of Biologically Treating Sulfite Waste Liquor**
(Based on waste liquor actually processed[2])

| Treatment Process | Maximum Loading (lb. B.O.D. per cu. yd. per day) | Removal of 5-day B.O.D. (%) | |
|---|---|---|---|
| | | Maximum | Indicated Practical |
| Disposal Processes: | | | |
| Activated sludge[1] | 1.7 | 95 | — |
| Foam phase[1] | 3.4 | 88 | 80 to 85 |
| Trickling filter | 6.4 | 81 | 65 to 70 |
| Contact aeration | 9.5 | 86 | 70 to 75 |
| Utilization Processes: | | | |
| Anaerobic methane | 1.5 | 80 | 60 to 70 |
| Acetone-butanol[1] | 45.0 | 79 | — |
| Lactic acid[1] | 45.0 | — | — |
| Ethyl alcohol | — | 55 | — |
| Plant No. 1[1] | 61.0 | — | 45 to 50 |
| Plant No. 2[1] | 78.0 | — | 45 to 50 |
| *Torula* yeast | 102.0 | 83 | 70 to 75 |

[1] Data obtained directly or calculated from published reports.

[2] The degree of waste liquor recovery possible from the washed pulp is a controversial issue dependant on conditions at the individual pulp mill. Estimates range from 60 per cent from primary drainage to more than 90 per cent with use of special equipment.

Large-scale laboratory, pilot plant, and commercial plant evaluations have usually shown the practical B.O.D. removals that any one process is capable of turning out routinely to be materially less than the potential as determined under optimum conditions, at low loadings, and for short periods of time.

Considered from the standpoints of loading capacity and the potential and practical B.O.D. removals, the *Torula* yeast process has proven to be of greatest immediate interest in the work being done. Performance reported for that process results from intensive research development over a period of years in the laboratories engaged in the program, in addition to work done in Germany and elsewhere. Similar expenditures of effort on certain of the other biological processes could conceivably lead to similar close definition of optimum conditions and with similar or even superior performance expectations. It is believed that all the biological processes studied are capable of being improved on to an appreciable extent.

## Discussion

Experience with biological treatment of SWL has served to show rather conclusively that, in order to be practical, a process should meet certain minimum requirements.

First, the process must be capable of handling very heavy loading in order to keep the capital investment within reason. Treatment of such strong

waste products as spent sulfite liquor at conventional loading rates would require relatively enormous treatment plants, the capital charges for which would be increased by the need for acid-resisting materials throughout. The loading which any process can handle will obviously have direct and important effects on the size requirements, and hence on construction expense. Calculations indicate the cost of treatment facilities of the standard "disposal type" to range into several million dollars to handle the waste from a 100-ton pulp mill, if such processes were to be adopted in their present stage of development. Investments of this order approach that of an entire pulp mill.

Secondly, the process should be capable of removing a minimum of 65 per cent of the 5-day B.O.D. from the waste liquor processed. Stream pollution cannot be expected to be greatly improved by the treatment of such strong wastes unless somewhat more than one-half the 5-day B.O.D. is removed. An arbitrary figure of 65 per cent reduction has been set as a minimum standard on which to judge a process in the investigations. Other situations and other wastes may dictate different minimum standards.

The remaining major requirement is that there must be a substantial recovery of values from the process to offset a portion of the operating charges. With sulfite liquor, the requirement for nitrogen and phosphorus nutrients involves hundreds of dollars per day in those processes operating aerobically, such as the trickling filter, activated sludge, and yeast production. The recovery of products may be very expensive in terms of power, steam, equipment, and skilled labor. To balance these and many other costs it is imperative to recover products which can be sold in large volume to stable markets. So large are the potential production volumes of the various products which could be produced from spent sulfite liquor that it is difficult to conceive of markets being developed to absorb many of them. This consideration alone may be the final basis on which the practical feasibility of a process is to be judged.

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# INDUSTRIAL WASTE LAGOONS *

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There are few known methods of waste treatment whereby a strong industrial waste can be treated economically to produce an effluent sufficiently low in B.O.D. that it can be discharged into a small stream without causing complaints. This paper stresses various methods of lagooning of cannery and slaughterhouse wastes, which are strictly organic in nature and are not toxic.

Many canning plants are located outside the corporate boundaries of cities and villages and are not served by sewer systems connected to sewage treatment plants. They must work out their own problems. In general, the plants are in operation 4 to 6 months a year when the rainfall is low and there is little or no flow in the nearby streams.

Where adequate facilities are available the discharge of trade wastes to the municipal sewers and treatment plant is the most economical and satisfactory arrangement. It is usually not feasible to handle cannery wastes in this fashion, however, because of the strength, volume, and seasonal production of such wastes.

The volume and strength of cannery waste from the processing of fruits and vegetables varies over a wide range. Wastes from plants which preserve or quick-freeze are similar in strength. The harvested fruits or vegetables are thoroughly washed, sorted, graded, and blanched. The product, which is preserved in glass or tin containers, passes through the filling machines and the air is exhausted in the hot water exhauster. The container is then sealed, cooked in retorts, and cooled.

The process waste consists of wash water; solids from sorting, peeling, and coring operations; blancher water; spillage from the filling and sealing machines; and wash water from cleaning floors, tables, walls, belts, etc., at end of the work day. The cooling water is not process water.

Cannery waste differs in many respects from sewage, in that it contains protein, carbohydrates, fats, a small amount of crude fiber, mineral salts, and organic acids. The blanching operation, basic for many vegetables and some fruits, is a process in which the raw food material is immersed in hot water or exposed to live steam. This treatment inhibits further enzymic action, which enhances the keeping quality of the product. Sewage, in turn, contains enzymes, end products of digestion, and large numbers of bacteria. Raw sewage solids can be easily digested, whereas cannery waste solids alone do not digest to any extent, being low in bacteria and tending to ferment in a digester.

Slaughterhouse solids are quite easily digested especially in the presence of sewage solids.

## Lagooning Practice

Lagooning of waste, after passage through a mechanical screen of rotary or vibrating type, is often the only practical method of treating canning or slaughterhouse waste in rural districts or rural towns. Sufficient available land is necessary, as the holding

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time in a lagoon is a big factor in the reduction of B.O.D.

Lagoons can be classified as leaching lagoons or storage lagoons, depending on the type of soil. Warrick, Wisniewski, and Sanborn (1) classify them as irrigation fields, untreated lagoons, chemically treated lagoons, and surface treated lagoons. In western New York, near Lake Ontario, there are many drumlins or gravel beds deposited by glaciers. A few canners have located small lagoons over these deposits with good results. This is an economical method of disposal in a few locations, as the ground slopes toward Lake Ontario. Disposal of screened and settled waste by irrigation in porous soil is inexpensive, but there is always the danger of the liquid finding its way to nearby wells. The writer tried this method at one place where limestone was present. The liquid worked its way through the limestone and discharged into a stream 5 miles from the lagoon. This type of lagoon is not recommended for general use.

Untreated storage lagoons are always a source of odor nuisance. Storage lagoons treated with lime, soda ash, or caustic soda are also unsatisfactory from the standpoint of the writer's experience. Lagoons treated with sodium nitrate are satisfactory if sufficient amounts of the nitrate are added daily. Sanborn (2) recommends that sufficient sodium nitrate be added to satisfy 20 per cent of the 5-day B.O.D. Sodium nitrate contains approximately 56 per cent available oxygen, which is released in the active or nascent state.

In canning waste practice it is recommended that in starting the reaction in the lagoon it is necessary to add 150 to 200 lb. of sodium nitrate to the waste from the processing of 1,000 cases of 24 No. 2 cans. A No. 2 can contains 20 oz. of peas, corn, beets, etc. Usually, 25 gal. of water is used in producing one case of canned goods. A case or bushel of lima beans, tomatoes, and beets requires from 35 to 40 gal. of water for washing, blanching, clean-up, etc., exclusive of cooling and boiler water.

Cooling water from spray coolers or cooling canals, as well as rain water, run off water, boiler blown-down water, condensed steam, retort water, and other fairly clean water should be allowed to discharge to a nearby stream and not to the lagoon.

In treating lagoons it is the practice of a few operators to add sodium carbonate with sodium nitrate to raise the pH value.

There are many available methods for addition of sodium nitrate. The solution feed method is preferable. Dry feeders are satisfactory, but they must be constructed of stainless steel or other suitable alloy, as sodium nitrate, being a strong oxidizing compound, it will soon rust plain steel.

The operator can dissolve the nitrate in a barrel or drum and apply it to the screen effluent or lagoon by means of a spigot or valve. It is not necessary to dose proportionately with flow variations, but rather to add the calculated requirement during the work day. A mechanical stirring device will facilitate solution of the nitrate.

The reactions in a lagoon are quite complex. Although anaerobic bacteria predominate at the start, the oxygen from the nitrate favors development of aerobic bacteria obtained from the soil. Wave action plus sunlight plays a big part and the reduced sodium nitrate, in loosing its oxygen, sets free its sodium to form sodium carbonate and raise the pH value of the incoming acid organic waste. Odor conditions are less troublesome when the pH is slightly above 7.0. A high pH of 8.0 to 8.5 is not desirable, as it tends to upset the desired flora, fauna, and bacterial balance. From April 15 to November 15 various algae of the *chlorophyceae* classification grow to a point where the water is green. This is desirable, as the D.O. will increase to 15 to 18 p.p.m. during the daylight hours.

When this condition exists it is possible to reduce the sodium nitrate addition by 25 per cent.

Lagoons may be excavated in firm ground to an effective depth of 5 ft., with a dike (for free board) of 2 to 3 ft. The dike keeps out the surface water and confines the water in the lagoon. A lagoon should be sufficiently large to hold the waste for 5 to 6 months, and longer if possible. The outlet pipe should be set 1½ ft. from the bottom to insure that the sludge will not be drawn out and also to keep a certain amount of waste in the lagoon as seed for incoming waste the following year. There are usually two periods in a year when streams have high water—fall and spring. The outlet pipe should be installed at the end or downstream side of the lagoon to insure that clean water is discharged.

In estimating the land area required, a study must be made of the volume of waste to be treated and allowance made for the extra land needed because of the 1½ to 1 slope of the sides. For example, an acre of land covered to 3-ft. effective depth will hold approximately 1 m.g. of liquid, but due to the side slope this figure is reduced to 0.8 m.g. (or 1.33 m.g. at a 5-ft. depth). It is much better, if conditions warrant, to discharge lagoons in March or April. If a plant operates during the entire year it may be necessary to discharge two or three times a year.

Most wastes contain sufficient protein to establish a balanced diet for flora, fauna, and bacteria. In some cases, such as in fruit waste, the balance is lacking. The ammonia produced in the reduction of nitrate appears to safisfy the bacteria and the proper balance is established.

The cost of construction depends on the size of the lagoon. It is a waste of time to construct a lagoon by taking dirt from inside or outside to make an embankment. This dirt will not hold back 4 to 5 ft. of liquid, muskrats will work holes through the dikes, and erosion often will cause a leak to develop in the dike. Weed growth will develop in the lagoon and usually the base is uneven. The effective holding capacity is, therefore, far below calculated volumes. It is much better to employ an engineer to select and lay out a suitable plot that will be approved by the State health department.

All holding space should be in firm ground below grade. The dike should have a berm 10 to 12 ft. wide and need not be more than 2 ft. above the water level in the lagoon. The outlet may be arranged with an overflow weir, and also a pipe with the opening set 1½ ft. above the bottom. There should be some liquid and sludge in the lagoon at all times. Excavation of 1 acre to a 5-ft. depth, may cost between $2,000 and $2,500. If possible, gravity flow from the screen is preferable. The lagoon should be located at least 1,000 ft. from houses.

## Lagoon Operation Observations

The writer has seen or has had a part in designing many different types of lagoons. At one canning plant a number of holes, 20 ft. square and 10 ft. deep were dug in series and connected near the top by 4-in. pipes. The screened waste was discharged into the first lagoon, where 75 per cent of the settleable solids deposited out. The effluent, by displacement, passed through all five lagoons, the final effluent discharging into an orchard between rows of apples trees. Sodium nitrate was added to the screened plant effluent daily. The following spring nearly all the liquid had leached away and the settled solids were removed by means of a power shovel.

A unique treatment plant has been designed at Hanover, Pa., where the waste is screened and settled, sodium nitrate is added, and the liquor passes through a series of holding ponds or lagoons. The effluent from the last pond is pumped to long-armed, slow motion sprinklers, which spray the

liquid over a wide area. The rotary type sprinkler heads are connected to a rubber hose and can be moved from place to place over a wide area.

At another plant, where there is year-round operation, the waste is screened and then sprayed onto Dunbar filters composed of a 6-in. top layer of anthrafilt over 24 in. of pea gravel and 1-in. and 2-in. limestone. Three filters are arranged in parallel, and as soon as solids cover any one bed to a point where there is too great loss of head, the flow is switched to another bed. The limestone tends to raise the pH value from a low of 4.2 to between 6.6 and 7.0. Discharge onto the bed is during a work day of 10 to 16 hr., but the effluent passes from the bed over the entire 24 hr. The final effluent during light packs goes directly to a small stream and passes over a series of ripples in the stream to its junction with a larger stream 1¼ miles downstream.

When the cherry and tomato packs are handled, the Dunbar filter effluent discharges to a series of holding beds where sodium nitrate is added daily. These holding beds are discharged to the stream the following spring.

At one slaughterhouse near Rochester, N. Y., there is a lagoon of the "flowing-through" or displacement type. The treatment plant consists of a grease trap in the basement of the sausage plant, a settling tank near the killing floor, and a sand and gravel filter which receives all liquid waste from settling basin and grease trap. The filter effluent then receives the sodium nitrate addition and flows by gravity to the lagoon. This type of waste is high in protein and nitrogen, so that the water in the lagoon is green from algae growth during most of the year. Ground water seeps into the lagoon and dilutes the waste. This is desirable. The B.O.D. at the end of the rectangular lagoon is seldom more than 35 p.p.m. and dissolved oxygen is always present.

There are many modifications possible with lagoons. The organic waste must be screened, and can—and often should be—settled. Following the rest period of 5 to 6 months in a lagoon, it can be discharged to a sand filter and chlorinated if necessary.

Silage liquid waste from pea, lima bean, or corn stacks should never be allowed to discharge to a lagoon. The B.O.D. of these liquids is too high (20,000 to 70,000 p.p.m.). Wastes having more than 3,600 p.p.m. B.O.D. do not work well in a lagoon due to the danger of odor and the cost of the high sodium nitrate dosage required. A lagoon can be located near a plant but prevailing winds must be considered so that any odors, especially at the start of operation, will not be carried back to the plant or drift by any village or group of houses.

There are one or two installations of lagoons in series in western New York, where beets constitute the main vegetable pack. At both plants the lagoon is divided. The solids settle out in the first lagoon. When the receiving lagoon is filled a valve is opened and the clarified liquid is discharged to the second lagoon. Only liquid from the second lagoon is discharged to the stream in the spring. A lye-peeled beet waste is not as easily handled as are other types of vegetable waste.

The New York State Health Department requires that all sanitary sewage be treated separately. The writer agrees in part with this requirement, but also sees a point in allowing septic tank effluent to be discharged to the existing lagoon, as desirable bacteria would be added to the lagoon. Although it is not desirable to add any chlorine or other disinfectant to the lagoon influent, it may be desirable to chlorinate the effluent if the receiving stream is used as a source of drinking water or for other purposes involving health.

Removal of sludge from a lagoon may be an expense after a period of years.

The majority of lagoons in present use are not well constructed, and weed growth tends to use the sludge for its food needs. A well-constructed lagoon will not have a weed problem and there is no danger from breaks in the dikes. Settleable solids can be settled out in a clarifier ahead of the lagoon. The settled sludge must be pumped or drawn from the clarifier daily or weekly to avoid septic conditions, with resultant odors.

Winter storage of lagooned wastes has shown B.O.D. reductions far in excess of results expected, as little bacterial action can be a factor during this period. Reported results indicate that freezing of the liquid caused nearly all suspended solids to settle out, along with many dissolved solids. These solids did not again go into solution and the clear liquid showed a 90 per cent reduction in B.O.D. Sodium nitrate presently costs around $60 per ton in car lots, although the price may drop in the near future.

When a lagoon is balanced and working satisfactorily small bubbles of nitrogen can be seen rising and discharging to the air.

It is desirable for sunlight to penetrate to the bottom of the lagoon. Wave action or ripples on the surface add oxygen to the liquid.

### Summary

Lagoons are practical where ample land is available. When sufficient sodium nitrate is added daily a lagoon need not be located more than 500 ft. from houses. In cannery waste there is little opportunity for recovery of saleable by-products. This approach can be discounted.

Industry must construct waste treatment plants from capital and not from earnings. The plant can be maintained and operated from earnings. Because of the character of their wastes most canneries and many slaughterhouses are restricted by economic considerations to disposal by lagooning, which method—properly applied—can be practical and successful.

### References

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## DISCUSSION

By Glenn Searls

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Mr. Ryan's paper clearly outlines the most economical methods of treating the types of wastes familiar to western New York. It is generally conceded by engineers and chemists in the waste treatment field that there is only one method that most industries can afford to install and operate. This is the type which consists of a screen, settling tank, and lagoon (or series of lagoons), with sodium nitrate treatment.

Many industrial wastes can be treated effectively in this manner. Of course, there are some types which require a greater degree of treatment before the effluent can be discharged into the receiving stream.

It seems fitting, in discussing Mr. Ryan's paper, to mention some of the costs connected with the construction of lagoons and their appurtenances.

Vibrating screens complete with motors, pumps, etc., range from $1,800 to

$3,000, depending on the size required for the job.

Cast iron pipe of 8-in. diameter ranges from $2.45 to $2.80 per linear foot; 12-in. diameter cast iron pipe ranges from $4.38 to $4.64 per linear foot. In the 12-in. diameter size, Transite sewer pipe costs $1.60 per ft.; steel pipe, $2.17 per ft.; wrought iron pipe, $4.90 per ft. The size and kind of pipe required depends largely on the nature and volume of the waste to be conveyed. For example, the cast iron pipe would be the most serviceable for wastes with a low pH.

Lagoon excavation runs from $0.35 to $0.50 per cu. yd., or $565 to $805 per acre-foot. Trenching, laying, and backfilling for pipe ranging from 6 in. to 12 in. in diameter costs from $2.25 to $2.50 per linear foot. Tunneling under highways and railroads costs about $150 per linear foot.

At prevailing prices, the cost of constructing a treatment works such as described by Mr. Ryan would be somewhere between $35,000 and $60,000.

From these data, it readily can be seen that many of the canneries and other food processing plants will find the cost of building such a treatment works prohibitive unless the expenditure can be spread over a period of years.

In conclusion, it should be stressed that although the lagoon type of waste treatment is often the most economical, there is in reality no inexpensive method. As is pointed out, even this method involves an expenditure of from $35,000 to $60,000.

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## CYANIDE WASTE SURVEY AT ROCKFORD, ILL.

A survey begun September 20, 1949, to determine the source and concentration of cyanide wastes entering the sewage treatment plant of the Rockford (Ill.) Sanitary District, has disclosed that the two principal sources of wastes containing cyanide are industrial plants carrying on heat-treating and plating of metals. According to Paul R. Carlson, chemist of the District, personal interviews with the individuals in responsible charge of the various industrial plants, as well as inspections of plant premises, met with favorable response in every instance. The opportunity was seized at many of the calls to mention the availability of literature on a method for satisfactory treatment of this type of waste and details of the process.

Considerable variation was evidenced in volumes and concentrations of cyanide salt solutions reaching the sewers. All plants dumping batches of cyanide wastes have been instructed to release their solutions at low flow rates and on a schedule set up by the District, thus affording greater dilution and obviating plant operational upsets.

Chemical analyses of plant effluent show cyanide concentrations ranging from 0.75 to 3.0 p.p.m. Although this concentration will kill fish, 60 to 100 dilutions with the water of the receiving stream (Rock River) should give flows non-toxic to fish. Of equal importance with the desire to trace the effects of cyanide wastes on fish life is the help this survey will undoubtedly give in determining the effects of these wastes on sludge digestion and other operations of the sewage treatment process.

# CHARACTERISTICS AND TREATMENT OF WOOL DYEING WASTES *

By Joseph A. McCarthy

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An account of the work of the Lawrence Experiment Station of the Massachusetts Department of Public Health on wool scouring wastes has already been published (1). The present paper is a report on the work of the Station on another important group of textile wastes—those from wool dyeing processes. Much of the work was done on acid chrome dyeing, in which the wool is colored in a bath containing the dissolved dyes in acid solution, with acetic as the most commonly used acid. The direct dyeing is followed by treatment with chrome salts, which produce a chromium lake on the fiber. Treating with mordants, generally chrome salts, may precede the dyeing bath, but in either case the resulting wastes are quite similar.

The wastes may vary greatly in concentration, depending on the condition and type of wool treated, the volume of water used, and particularly on the type of dye used, as some dyes may be run much nearer to exhaustion than others, with resulting differences in the quantity and character of organic materials discharged from the bath, and especially in the color of the waste. The amount and kind of acid and of reducing substances also materially affect the character of the waste. However, all the wastes examined were much weaker than those from wool scouring. Table I shows the analyses of several typical samples of dye wastes at the end of the dyeing operation and preceding any rinsing operation. The figures show a fairly wide range in all the analyses, especially in color and B.O.D., but it is noticeable that the variation in dissolved solids is relatively small, and only one of the samples, that containing red dye, was high in ether soluble substances, a large part of which was not grease or fats. This waste had the highest color of any samples examined and was also very high in B.O.D., apparently as a result of considerable unspent dyestuff remaining. The brown sample, which had the lowest pH, 4.3, contained more than the usual amount of organic acid, a condition reflected in the high B.O.D.

The amount of rinse water in dyeing operations, as might be expected, varies widely with local operating conditions, the kind of dye, the condition of the wool, and oftentimes the amount of clean water available. Apparently, practically no water is re-used in ordinary practice. The volume of water used in rinsing may run from 1 to 10 times the volume used in the original dyebath, with an average of from 2 to 3 times. The total volume of waste per pound of wool, therefore, also varies widely, with an average in the plants examined generally not much in excess of 1 gal. of water for dyeing 1 lb. of wool. Many other mills are reported to use much higher volumes.

As most mills use the same drains for discharging strong wastes and rinse waters, with ordinarily no attempt at segregation, the mixed dumps and rinses were used in practically all the

* Presented at 1949 Spring Meeting, New England Sewage Works Association; Bristol, Conn.; May 25, 1949.

**TABLE I.—Analyses of Dye Waste Dumps**

| Dye | Color (p.p.m.) | Diss. Sol. (p.p.m.) | | Susp. Sol. (p.p.m.) | | pH | N[1] (p.p.m.) | Alk. (p.p.m.) | Fats[2] (p.p.m.) | Oxygen Cons. (p.p.m.) | 5-Day B.O.D. (p.p.m.) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | Vol. | Total | Vol. | | | | | | |
| Red | 1,000 | 2,670 | 820 | 185 | 46 | 5.2 | 22 | 1,640 | 590 | 270 | 3,700 |
| Brown | 740 | 1,300 | 420 | 104 | 34 | 5.3 | 13 | 920 | 120 | 140 | 1,650 |
| Black | 900 | 1,590 | 540 | 113 | 37 | 5.6 | 7 | 970 | 78 | 230 | 1,290 |
| Blue | 650 | 1,620 | 670 | 150 | 56 | 6.3 | 21 | 900 | 100 | 100 | 1,020 |
| Mixed | 780 | 1,640 | 640 | 140 | 45 | 5.4 | 14 | 980 | 160 | 160 | 1,230 |
| Brown | 290 | 2,200 | 1,000 | 7 | 4 | 4.3 | 10 | 610 | 60 | 210 | 4,300 |
| Mixed | 240 | 1,770 | 570 | 12 | 6 | 4.4 | 12 | 1,680 | 50 | 240 | 2,000 |

[1] Kjeldahl nitrogen. [2] Substances soluble in ethyl ether.

work. In many mills domestic sewage is discharged through the same drains. Two of the examples given include such sewage, which apparently has little effect, as the two examples are quite similar to the others shown. Table II shows analyses of these mixtures. The range in strength is, of course, quite similar to that observed in the undiluted wastes; in B.O.D., the mixtures vary from about the strength of strong domestic sewage to 3 or 4 times as great.

Table III shows the stream polluting constituents of such mixtures in terms of pounds per 100 lb. of wool dyed. In only one case is there shown an amount of 5-day B.O.D. equal to 1 per cent of the weight of the wool handled, and the average is about ½ lb. For wool scourings an average of over 9 lb. per 100 lb. of wool scoured has been reported (1). The amount of grease (0.056 lb.) in dye wastes is insignificant as compared to the 9.6 lb. for wool scourings, and the dissolved and suspended solids are likewise much less.

The significance of dye wastes from a stream pollution standpoint is increased, however, from the fact that wool may be dyed in the top before spinning, as yarn after spinning, and in cloth after weaving, and the same wool may be dyed and washed several times in each stage of manufacture. The Massachusetts Department of Public Health investigation of the Merrimack River in 1946 indicated a volume of about 7.5 m.g.d. of dye wastes as compared to 2.6 m.g.d. of wool scourings. If the shrinkage in wool is taken into consideration, this could indicate that about 5 times as much volume of waste is produced in dyeing as in scouring per 100 lb. of

**TABLE II.—Analyses of Dye Wastes, Including Rinse Water (in P.P.M.)**

| Sample | Diss. Sol. | | Susp. Sol. | | N[1] | Alk. | Fats[2] | 5-Day B.O.D. |
|---|---|---|---|---|---|---|---|---|
| | Total | Vol. | Total | Vol. | | | | |
| A | 890 | 300 | 63 | 17 | 7 | 540 | 210 | 1,240 |
| B | 440 | 140 | 61 | 18 | 4 | 290 | 38 | 550 |
| C | 540 | 150 | 116 | 38 | 3 | 320 | 69 | 490 |
| D | 540 | 220 | 50 | 19 | 7 | 300 | 33 | 340 |
| E | 530 | 180 | 40 | 14 | 7 | 300 | 41 | 430 |
| F[3] | 780 | 240 | 196 | 93 | 8 | 370 | 80 | 960 |
| G[3] | 500 | 150 | 145 | 56 | 6 | 370 | 48 | 470 |
| Av. | 600 | 200 | 100 | 36 | 6 | 350 | 76 | 640 |

[1] Kjeldahl nitrogen. [2] Substances soluble in ethyl ether. [3] Includes sewage.

TABLE III.—Stream Polluting Constituents of Dye Wastes, Including Rinse Waters (In Lb. per 100 lb. of Wool Dyed)

| Sample | Diss. Solids | | Susp. Solids | | Alk. | Fats[1] | 5-Day B.O.D. |
|---|---|---|---|---|---|---|---|
| | Total | Vol. | Total | Vol. | | | |
| A | 0.74 | 0.25 | 0.053 | 0.014 | 0.47 | 0.17 | 1.03 |
| B | 0.37 | 0.12 | 0.051 | 0.015 | 0.24 | 0.032 | 0.46 |
| C | 0.45 | 0.13 | 0.097 | 0.032 | 0.27 | 0.058 | 0.41 |
| D | 0.45 | 0.19 | 0.041 | 0.016 | 0.25 | 0.028 | 0.28 |
| E | 0.44 | 0.15 | 0.033 | 0.012 | 0.25 | 0.034 | 0.36 |
| F[2] | 0.75 | 0.25 | 0.19 | 0.040 | 0.36 | 0.043 | 0.52 |
| G[2] | 0.48 | 0.14 | 0.13 | 0.050 | 0.36 | 0.025 | 0.25 |
| Av. | 0.53 | 0.18 | 0.085 | 0.026 | 0.31 | 0.056 | 0.47 |

[1] Substances soluble in ethyl ether. [2] Includes sewage.

wool, or it might be inferred that each pound of wool may be dyed and washed perhaps 4 to 5 times. On this basis, each 100 lb. of wool would produce B.O.D. equivalent to 12 to 15 persons.

## Treatment

Although the final wastes are weak as compared to wool scourings and may be discharged without treatment if sufficient dilution is available, there will be problems of disposal if a mill is located on a relatively small stream, particularly because of color. The low pH may also make direct discharge undesirable. If color is the only problem, chlorination to destroy the unspent dyes may afford sufficient treatment.

Analyses showed that there was very little suspended matter in the wastes, and that practically all the B.O.D. was in solution. Coagulation, therefore, proved to be ineffective; even prolonged sedimentation gives very little removal. This fact, and the large volumes involved, generally make lagooning an unsatisfactory solution. Successful treatment has been reported from certain plants which treat dye wastes with other textile wastes, or with relatively large volumes of domestic sewage.

Examinations showed that enough nitrogen was present in the wastes to give a reasonably satisfactory carbon-nitrogen ratio, and although small amounts of chromium were found, all in the trivalent state, the wastes always contained considerable numbers of bacteria. As these conditions indicated the possibility of biological treatment, four small trickling filters were started, each receiving one of the undiluted dumps shown in Table I, at a rate of about 1.5 m.g.a.d. The filters had been seeded with settled domestic sewage for a few days before application of waste was started. In spite of the very heavy loading, the filters soon began to nitrify. Analysis showed satisfactory reductions in B.O.D., grease, and suspended solids. The effect on color was particularly good. In spite of the heavy loading, only one effluent, that from the filter receiving red waste, showed any sign of the original color, and that had been reduced to a faint pink. The results of these runs are shown in Table IV. All of the analyses of the effluents quoted in this paper are on samples settled 1 hr., although in most cases there was very little settleable material in the effluent.

These results were so promising that a new set of four filters was started, receiving the same dumps, this time with rinse waters added in the proportions of dump and rinse used at the mill. Once more the results were very satisfactory. As shown in Table V, good nitrification was obtained, B.O.D. removals were greater than 90

**TABLE IV.—Results of Trickling Filter Operation with Dye Waste Dumps**

| Filter No. | Dye | | B.O.D. (lb. per acre-ft.) | pH | Parts per Million | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Diss. Sol. | | Susp. Sol. | | N[1] | Oxygen Cons. | Fats[2] | Alk. | 5-Day B.O.D. |
| | | | | | Total | Vol. | Total | Vol. | | | | | |
| 745 | Red | Applied | 5,150 | 5.2 | 2,670 | 820 | 185 | 46 | 22 | 274 | 590 | 1,640 | 3,700 |
| | | Effluent | — | 6.5 | 1,810 | 720 | 85 | 32 | 16 | 214 | 91 | 1,330 | 1,290 |
| | | % removed | — | — | 32 | 12 | 53 | 30 | 27 | 28 | 85 | 19 | 65 |
| 746 | Brown | Applied | 2,290 | 5.3 | 1,300 | 420 | 104 | 34 | 13 | 135 | 115 | 920 | 1,650 |
| | | Effluent | — | 6.8 | 800 | 250 | 65 | 33 | 9 | 100 | 43 | 730 | 550 |
| | | % removed | — | — | 38 | 41 | 38 | 3 | 32 | 26 | 63 | 21 | 67 |
| 747 | Black | Applied | 1,740 | 5.6 | 1,590 | 540 | 113 | 37 | 7.1 | 233 | 78 | 970 | 1,290 |
| | | Effluent | — | 7.3 | 1,630 | 670 | 56 | 25 | 6.7 | 120 | 44 | 670 | 560 |
| | | % removed | — | — | — | — | 50 | 32 | 6 | 48 | 46 | 31 | 57 |
| 749 | Blue | Applied | 1,270 | 6.3 | 1,620 | 670 | 150 | 56 | 21 | 100 | 100 | 900 | 1,020 |
| | | Effluent | — | 7.3 | 1,290 | 530 | 37 | 27 | 11 | 61 | 50 | 875 | 150 |
| | | % removed | — | — | 20 | 21 | 75 | 50 | 48 | 39 | 50 | 3 | 85 |

[1] Kjeldahl nitrogen. [2] Substances soluble in ethyl ether.

per cent, and grease was reduced to insignificant amounts. Particularly pleasing was the increase in pH to about 7 and the high removal of organic suspended solids. The effluents were quite stable. With the exception of the filter receiving the red mixture, the colors were low, and even in this effluent there was none of the original color remaining. Storage of the effluents for several weeks showed no return of color, indicating that the dyes had been completely broken up by the biological action.

**TABLE V.—Results of Trickling Filter Operation with Mixed Dye Waste Dumps and Rinse Waters**

| Filter No. | Dye | | B.O.D. (lb. per acre-ft.) | pH | Parts per Million | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Color | Diss. Sol. | | Susp. Sol. | | Nitrate Nitrogen | Oxygen Cons. | Fats[1] | 5-Day B.O.D. |
| | | | | | | Total | Vol. | Total | Vol. | | | | |
| 750 | Red | Applied | 4,600 | 5.6 | 340 | 900 | 300 | 64 | 19 | — | 113 | 240 | 1,230 |
| | | Effluent | — | 7.1 | 155 | 660 | 290 | 15 | 11 | 6.0 | 74 | 20 | 74 |
| | | % removed | — | — | 54 | 27 | 3 | 77 | 41 | — | 34 | 92 | 94 |
| 751 | Brown | Applied | 2,040 | 5.8 | 250 | 450 | 140 | 91 | 26 | — | 67 | 39 | 550 |
| | | Effluent | — | 6.9 | 72 | 390 | 130 | 17 | 12 | 4.0 | 29 | 28 | 52 |
| | | % removed | — | — | 71 | 13 | 7 | 81 | 54 | — | 56 | 28 | 90 |
| 752 | Black | Applied | 1,600 | 5.6 | 300 | 580 | 210 | 42 | 16 | — | 62 | 50 | 430 |
| | | Effluent | — | 7.1 | 95 | 400 | 210 | 10 | 7 | 3.1 | 32 | 30 | 13 |
| | | % removed | — | — | 68 | 31 | — | 76 | 56 | — | 49 | 40 | 97 |
| 753 | Blue | Applied | 1,450 | 6.5 | 220 | 540 | 220 | 74 | 22 | — | 40 | 35 | 390 |
| | | Effluent | — | 7.3 | 70 | 400 | 190 | 19 | 9 | 4.7 | 30 | 15 | 34 |
| | | % removed | — | — | 68 | 26 | 13 | 74 | 59 | — | 25 | 57 | 91 |

[1] Substances soluble in ethyl ether.

To study the limitations of filtration further, filters were then operated with various combinations of mixed and individual wastes and rinses, with and without domestic sewage, at various loadings. As shown in Table VI, loadings of the order of 1,500 to 2,000 lb. per acre-foot produced effluents highly satisfactory in color, suspended solids, grease, and B.O.D., provided the pH of the applied mixture was 5.5 or higher. When mixtures with a pH below 5.5 were applied, the possible loading was sharply decreased. In studying increased loading, an arbitrary standard was adopted for a satisfactory effluent—pH of 6.5 or higher, color of 100, and B.O.D. of 100. Most of the lower loadings produced effluents of considerably better quality. Such an effluent was of acceptable quality in one of the problems under consideration during this study. The degree of purification and the character of effluent required would depend, of course, on the capacity of the receiving stream or on other local conditions.

### Effect of Recirculation

Several recirculating trickling filters were also operated with similar combinations of mixed dumps and rinses, to each of which about 5 per cent domestic sewage was added. After considerable experimentation with recirculation ratio, it was decided that passage of from 4 to 6 times through the filter was sufficient to realize all the benefits of recirculation. One of these filters was operated with an initial load of 2,000 lb. per acre-foot, a primary rate of about 2 m.g.a.d. and a total rate of 10 m.g.a.d. The load was increased every 3 or 4 weeks. It was found possible to increase the initial load applied to about 4,000 lb. per acre-foot, with a

**TABLE VI.—Results of Trickling Filter Operation with Mixed Dye Waste Dumps and Rinse Waters**

| Filter No. | Dye | | B.O.D. (lb. per acre-ft.) | pH | Parts per Million | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Color | Diss. Sol. | | Susp. Sol. | | Nitrate Nitrogen | Oxygen Cons. | Fats[1] | 5-Day B.O.D. |
| | | | | | | Total | Vol. | Total | Vol. | | | | |
| 754 | Mixed | Applied | 2,280 | 5.5 | 200 | 1,020 | 340 | 300 | 80 | — | 90 | 69 | 950 |
| | | Effluent | — | 6.3 | 95 | 900 | 270 | 40 | 19 | 2.2 | 39 | 28 | 110 |
| | | % removed | — | — | 71 | 12 | 21 | 87 | 76 | — | 57 | 59 | 88 |
| 754A | Mixed | Applied | 2,440 | 5.8 | 240 | 540 | 150 | 116 | 38 | — | 59 | 69 | 640 |
| | | Effluent | — | 6.9 | 85 | 410 | 140 | 24 | 12 | 2.0 | 28 | 23 | 60 |
| | | % removed | — | — | 65 | 24 | 7 | 79 | 68 | — | 53 | 67 | 91 |
| 754B | Brown | Applied | 1,030 | 4.4 | 150 | 590 | 190 | 12 | 6 | — | 80 | 20 | 480 |
| | | Effluent | — | 6.0 | 120 | 560 | 180 | 11 | 6 | .20 | 62 | 18 | 120 |
| | | % removed | — | — | 20 | 5 | 5 | 8 | — | — | 23 | 10 | 75 |
| 754C | Mixed[2] | Applied | 1,520 | 5.5 | 280 | 860 | 260 | 192 | 31 | — | 79 | 53 | 608 |
| | | Effluent | — | 7.3 | 75 | 340 | 120 | 32 | 24 | .21 | 36 | 23 | 42 |
| | | % removed | — | — | 73 | 61 | 54 | 83 | 23 | — | 52 | 57 | 93 |
| 754D | Mixed[2] | Applied | 2,370 | 5.6 | 300 | 1,020 | 340 | 300 | 80 | — | 90 | 50 | 640 |
| | | Effluent | — | 7.2 | 95 | 340 | 100 | 18 | 12 | .25 | 34 | 23 | 60 |
| | | % removed | — | — | 68 | 67 | 71 | 94 | 85 | — | 62 | 54 | 91 |
| 755 | Mixed[2] | Applied | 3,540 | 5.1 | 260 | 780 | 240 | 220 | 113 | — | 55 | 45 | 960 |
| | | Effluent | — | 6.4 | 100 | 620 | 240 | 47 | 22 | .10 | 46 | 25 | 160 |
| | | % removed | — | — | 62 | 20 | — | 79 | 80 | — | 16 | 44 | 83 |

[1] Substances soluble in ethyl ether. [2] Domestic sewage added.

**TABLE VII.—Results of Recirculated Trickling Filter Operation with Mixed Dye Waste Dumps, Rinse Waters, and Domestic Sewage [1]**

| Filter No. 736 | B.O.D. (lb. per acre-ft.) | pH | Parts per Million | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Color | Diss. Sol. | | Susp. Sol. | | Nitrate Nitrogen | Oxygen Cons. | Fats[2] | 5-Day B.O.D. |
| | | | | Total | Vol. | Total | Vol. | | | | |
| Applied | 2,000 | 5.9 | — | 500 | 150 | 145 | 56 | — | 47 | 48 | 470 |
| Effluent | — | 7.1 | 100 | 420 | 150 | 26 | 16 | 1.8 | 32 | 25 | 42 |
| % removed | — | — | — | 16 | — | 82 | 72 | — | 32 | 48 | 92 |
| Applied | 3,750 | 5.3 | — | 610 | 190 | 63 | 33 | — | 63 | 60 | 900 |
| Effluent | — | 7.4 | 87 | 500 | 140 | 28 | 17 | 5.4 | 42 | 25 | 53 |
| % removed | — | — | — | 18 | 26 | 55 | 49 | — | 33 | 58 | 94 |
| Applied | 3,920 | 5.1 | — | 640 | 200 | 75 | 33 | — | 56 | 45 | 940 |
| Effluent | — | 7.3 | 83 | 460 | 100 | 36 | 16 | 0.2 | 46 | 28 | 60 |
| % removed | — | — | — | 31 | 50 | 52 | 51 | — | 18 | 38 | 93 |
| Applied | 5,000 | 5.3 | — | 640 | 200 | 75 | 33 | — | 59 | 65 | 1,200 |
| Effluent | — | 7.5 | 140 | 480 | 120 | 46 | 25 | 1.9 | 41 | 35 | 125 |
| % removed | — | — | — | 25 | 40 | 39 | 24 | — | 30 | 46 | 89 |

[1] About 5 per cent. [2] Substances soluble in ethyl ether.

primary rate of over 4 m.g.a.d. and a total rate of about 24 m.g.a.d., before the character of the effluent showed serious deterioration. It was also found that a recirculating filter would give satisfactory treatment on wastes with a pH averaging 5.1 and occasionally running as acid as 4.8, or considerably more acid than could be applied to single-pass filters. Table VII shows the results of the operation of this filter.

## Vat Dyeing Wastes

All the wastes thus far considered have been from the acid bath process. Vat dyeing is materially different. Used sometimes on wool alone, it is used more frequently on mixtures of wool and other materials, especially rayon. In this process, the fiber is first treated in the dye kettle with a reducing substance. Then the reduced dye is added in extremely alkaline solution, the fiber is circulated for a short time, and the kettle is drained. After a brief rinse, bicarbonate and/or oxidizing materials are added to the bath, circulation follows, and this charge is dumped. Following another rinse, an acetic acid solution is added to set the dye and remove any unused dye, and then there is a final rinse. The waste from the first part of the process is very strongly alkaline (pH 11 to 12), is low in suspended solids, and has a B.O.D. of about 1,000 p.p.m. The second dump is quite clear, very weak in B.O.D., and has a pH of about 9. The acid dump has a pH of about 5, a fair amount of suspended solids, and a B.O.D. of 1,000 p.p.m. or more. When the three dumps and the accompanying rinses are mixed together chemical reactions produce considerable suspended matter, which settles rapidly and almost completely in 2 to 4 hr. The pH of such mixtures is about 9, and the B.O.D. is generally less than 1,000 p.p.m. Carbonation of the mixed wastes quickly removes suspended solids, but neither carbonation nor plain settling precipitates much of the B.O.D., which is practically all in solution. Table VIII shows the average analysis of several sets of these wastes before and after settling. The volume of vat dyeing wastes is generally considerably greater per pound of wool than that from acid dyeing.

**TABLE VIII.—Average Analyses of Vat Top Dyeing Wastes**

| Sample | pH | Parts per Million | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Diss. Sol. | | Susp. Sol. | | Oxygen Cons. | Fats[1] | Alkalinity | | 5-Day B.O.D. |
| | | Total | Vol. | Total | Vol. | | | Total | Caustic | |
| Part I (alkaline) | 11.2 | 23,400 | 5,400 | 42 | 36 | 520 | 100 | 2,450 | 1,270 | 1,080 |
| Part II (bicarbonate) | 9.8 | 2,150 | 110 | 11 | 6 | 45 | 20 | 1,870 | 440 | 23 |
| Part III (acid) | 5.3 | 2,000 | 530 | 110 | 21 | 42 | 180 | 610 | 0 | 1,300 |
| Mixed wastes | 9.5 | 9,600 | 2,600 | 270 | 165 | 230 | 100 | 1,820 | 240 | 780 |
| Mixed wastes with rinse waters | 9.4 | 5,300 | 1,450 | 150 | 95 | 120 | 50 | 1,100 | 240 | 440 |
| Mixed wastes with rinse waters; settled 4 hr. | 9.3 | 5,200 | 1,400 | 20 | 15 | 120 | 20 | 1,100 | 230 | 420 |
| Mixed wastes with rinse waters; carbonated and settled 2 hr. | 7.6 | 4,700 | 780 | 25 | 12 | 70 | 18 | 1,060 | 0 | 420 |

[1] Substances soluble in ethyl ether.

## Treatment of Vat Wastes

Treatment of vat wastes on trickling filters showed that although the settled alkaline wastes were weaker in B.O.D. than the acid dye wastes, a rate of about 1.5 m.g.a.d., with a filter loading of about 1,000 lb. per acre-foot, was the limit for single-pass filtration. Recirculation experiments showed that a ratio of 9:1 was necessary to give any real benefit, and even with this high recirculation, which brought about a total rate of 20 m.g.a.d., the limiting load was only 30 to 40 per cent higher than with straight filtration. Carbonation of the wastes permitted a loading similar to recirculation. Apparently, the high pH interfered more seriously with good filtration than did the organic load. Table IX shows the results of these studies.

**TABLE IX.—Results of Trickling Filter Operations with Vat Dyeing Wastes**

| Filter No. | | B.O.D. (lb. per acre-ft.) | pH | Parts per Million | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Color | Susp. Solids | | Nitrate Nitrogen | Oxygen Cons. | Alkalinity | | 5-Day B.O.D. |
| | | | | | Total | Volatile | | | Total | Caustic | |
| 757 | Applied | 900 | 9.4 | — | 29 | 18 | — | 74 | 470 | 50 | 260 |
| | Effluent | — | 8.2 | 45 | 18 | 13 | 1.6 | 42 | 360 | 2 | 77 |
| | % removed | — | — | — | 38 | 28 | — | 43 | 23 | 96 | 70 |
| 757 | Applied | 1,080 | 9.3 | — | 25 | 11 | — | 87 | 680 | 90 | 310 |
| | Effluent | — | 8.4 | 52 | 13 | 11 | 2.1 | 57 | 600 | 15 | 100 |
| | % removed | — | — | — | 48 | — | — | 35 | 12 | 83 | 68 |
| 758[1] | Applied | 1,200 | 9.3 | — | 30 | 22 | — | 97 | 680 | 95 | 330 |
| | Effluent | — | 8.2 | 73 | 20 | 13 | 0.8 | 37 | 590 | 3 | 70 |
| | % removed | — | — | — | 33 | 41 | — | 62 | 13 | 97 | 79 |
| 759[2] | Applied | 1,200 | 8.2 | — | 31 | 27 | — | 98 | 640 | 10 | 230 |
| | Effluent | — | 7.9 | 65 | 10 | 8 | 4.0 | 54 | 550 | 0 | 72 |
| | % removed | — | — | — | 68 | 70 | — | 45 | 14 | — | 69 |

[1] Recirculation. [2] Carbonated wastes.

**TABLE X.—Analyses of Mixtures of Acid and Vat Dyeing Wastes and Rinses**

| Brown Acid Waste and Rinse (%) | Vat Waste and Rinse (%) | Settling Time (hr.) | pH | Parts per Million | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Diss. Sol. | | Susp. Sol. | | Oxygen Cons. | Fats[1] | Alk. | 5-Day B.O.D. |
| | | | | Total | Vol. | Total | Vol. | | | | |
| 90 | 10 | 0 | 4.4 | 900 | 500 | 3 | 2 | 67 | 35 | 340 | 1,580 |
| 90 | 10 | 24 | 4.5 | 890 | 500 | 3 | 2 | 52 | 20 | 340 | 1,480 |
| 75 | 25 | 0 | 4.5 | 1,770 | 570 | 22 | 19 | 58 | 32 | 340 | 1,380 |
| 75 | 25 | 2 | 4.4 | 1,570 | 390 | 12 | 9 | 48 | 22 | 320 | 1,300 |
| 75 | 25 | 5 | 4.4 | 1,500 | 330 | 8 | 7 | 48 | 20 | 320 | 1,180 |

[1] Substances soluble in ethyl ether.

## Mixed Wastes

Because both acid and alkaline dyeing processes may be in use at the same mill at the same time, several sets of samples of mixed wastes and rinses were obtained and analyzed. The proportion of acid waste was from 75 to 90 per cent of the total discharge and the acid wastes were very strong. The mixed wastes were low in pH and very low in suspended matter. Sedimentation removed very little suspended solids or B.O.D. Typical analyses of the mixtures are shown in Table X.

## Treatment of Mixed Wastes

Filtration experiments on mixed wastes with a small amount of domestic sewage indicated a loading limit of not much more than 1,000 lb. per acre-foot. Recirculation increased the maximum permissible loading by only a comparatively small degree. Results of these tests are shown in Table XI. The mixtures applied to these filters were considerably weaker, especially in B.O.D. and suspended solids, than those applied to filters operated with acid waste mixtures.

Apparently, the large proportion of very strong and excessively acid waste in the mixture applied to this filter materially diminished the permissible loading. Later experiments, in which approximately equal parts of alkaline waste and a more normal acid waste were applied to a filter, indicated that

**TABLE XI. Results of Trickling Filter Operation with Mixtures of Acid and Vat Dyeing Wastes and Rinses, with Sewage Added**

| Filter No. | | B.O.D. (lb. per acre-ft.) | pH | Parts per Million | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Color | Susp. Sol. | | Oxygen Cons. | Nitrate Nitrogen | Alk. | 5-Day B.O.D. |
| | | | | | Total | Vol. | | | | |
| 760 | Applied | 1,210 | 5.1 | — | 32 | 10 | 52 | — | 340 | 480 |
| | Effluent | — | 6.8 | 67 | 11 | 6 | 31 | 0.73 | 250 | 100 |
| | % removed | — | — | — | 68 | 40 | 40 | — | 26 | 79 |
| 761 | Applied | 1,130 | 5.1 | — | 32 | 13 | 48 | — | 320 | 450 |
| | Effluent | — | 7.0 | 77 | 7 | 5 | 24 | 0.18 | 230 | 90 |
| | % removed | — | — | — | 78 | 62 | 50 | — | 28 | 80 |
| 763[1] | Applied | 1,470 | 4.9 | — | 60 | 22 | 49 | — | 280 | 440 |
| | Effluent | — | 7.0 | 90 | 21 | 15 | 22 | 0.41 | 200 | 93 |
| | % removed | — | — | — | 65 | 31 | 55 | — | 29 | 79 |

[1] Recirculation.

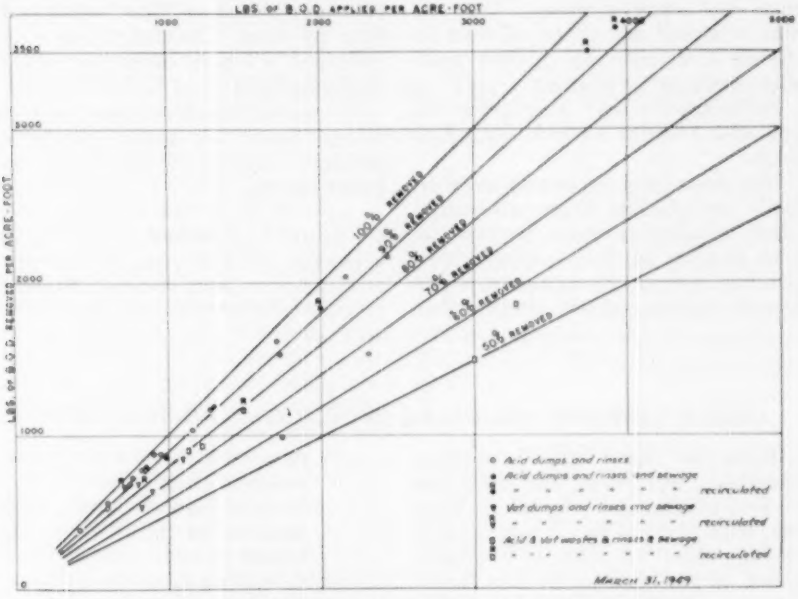


**FIGURE 1.—Trickling filter operation with dyeing wastes.**

successful filtration could be obtained with loadings up to at least 1,500 lb. per acre-foot. The action of filters Nos. 760 and 761, as shown in Table XI, further emphasizes the deleterious effect of extremely high or extremely low pH on filtration.

## Sedimentation

Although neither acid nor alkaline wastes contain much suspended material and normal sedimentation does not effect much removal of this matter, it has been found desirable in handling mixed wastes to allow a considerable period of mixing. In plant installations it would be advisable to provide equalization tanks with capacity sufficient for at least 8 to 12 hr. of flow, thus providing for thorough mixing of wastes varying in color, strength, and acidity or alkalinity. If domestic sewage is to be applied to a trickling filter with the wastes, it would be preferable to exclude it from the equalizing tank and to mix it with the settled wastes immediately before application to the filter.

The amount of sludge from such equalizing tanks would be comparatively small. In the experiments reported the total solids from settling of both the applied waste and the trickling filter effluents amounted to from 300 to 800 lb. per m.g. of waste treated. The sludge dried readily, and experiments showed that it would digest equally readily.

In Figure 1 is shown the amount of B.O.D. loading on each of the filters, the amount removed by filtration, and the percentage of removal. In most cases the removal is higher than that normally expected from filters receiving similar loadings of domestic sewage alone. The poorer performances are associated in almost every case with abnormally high or low pH.

## Summary

Wool dyeing wastes are stronger than domestic sewage, but much weaker

than wool scouring wastes. The volume produced per pound of wool in dyeing is considerably greater than that produced by scouring.

Sedimentation and coagulation do not offer effective methods for treatment.

The waste may be treated satisfactorily on trickling filters, preferably after equalization, with loadings at least as great as those employed with domestic sewage. Recirculation makes heavier loading possible. High or low pH markedly reduces filter loading and filter efficiency. The sludge from such treatment is low in volume and readily disposed of.

Dye wastes introduced into domestic sewage should not present insoluble problems outside, of course, of the added loading.

### Reference

1. McCarthy, J. A., "A Method for Treatment of Wool Scouring Wastes." THIS JOURNAL, **21**, 1, 75 (Jan., 1949).

## CHECK LIST FOR REDUCING INDUSTRIAL WASTE COSTS

Industrial liquid waste treatment operations, equipment, and costs can be held to a minimum by taking steps like those outlined in a "management checkup chart" of points to be investigated, as published by *Modern Industry* (Dec., 1949, p. 48) in an informative article on the problem. The possibilities outlined include:

1. Changing processing methods so liquid waste is not produced (for example, abrasive blasting instead of acid pickling).
2. Minimizing the amount of liquid that will need treatment by:
   a. Providing for recirculation and re-use of liquids (closed or partially closed systems).
   b. Substituting spray methods for dipping, and carefully controlling amount of spray.
   c. Curbing the rate of water flow in rinse tanks, coolers, etc.
   d. Segregating storm water.
3. Minimizing concentration of contaminants in water by:
   a. Tightening up on plant housekeeping (reducing acid and oil drips in floor washes).
   b. Reducing carry-over of chemicals from treatment tanks to rinse tanks to reduce contamination of rinse water.
   c. Keeping separate wastes (oils, creosote, etc.) that can be burned or sold.
   d. Scheduling dumping of concentrated chemicals to ease treatment plant loads, or at least holding them for periods of high flow in streams.
4. Making better use of municipal sewage treatment facilities by:
   a. Partially treating wastes so they can be accepted by city plants.
   b. Contributing to the planning and helping to defray the cost of construction of additional facilities that will make it possible for city sewage plants to handle industrial wastes.
5. Reducing waste disposal plant operating costs by:
   a. Making the plant itself as automatic as possible.
   b. Using one waste to help treat another and thus cut the cost of treatment chemicals.
   c. Finding a market for oils and other materials separated during treatment.

# BIOLOGICAL OXIDATION OF INDUSTRIAL WASTES*

By H. Heukelekian

Biological oxidation of industrial wastes presents some problems not commonly encountered in the treatment of domestic sewage. Domestic sewage is more nearly uniform in composition, is relatively more dilute, is more nearly balanced food for microorganisms than are most wastes, and is non-toxic. Industrial wastes vary from purely carbonaceous materials, such as sugars and starches, to purely nitrogeneous materials, such as slaughterhouse wastes. Some are mainly oily and fatty in nature. Most industrial wastes, however, contain varying mixtures of these types of compounds. Domestic sewage contains coarse and finely suspended and dissolved materials. In some wastes only dissolved materials may be present, whereas in others the solids may be primarily in fine or coarse suspension. Most of them, however, contain mixtures of suspended and dissolved solids. The inorganic matter in domestic sewage varies within narrow limits in different locations, whereas industrial wastes may be purely inorganic or predominantly organic. Domestic sewage from different sources varies in strength only within narrow limits. It usually has a B.O.D. of 100 to 350 p.p.m. Most industrial wastes have B.O.D. values in excess of this, a great number having a B.O.D. value of 1,000 to 5,000 p.p.m., with some running as high as 10,000 to 50,000 p.p.m. Domestic sewage does not contain any inhibiting materials to biological life, whereas some industrial wastes contain toxic compounds.

All these differences raise special problems in the biological oxidation of wastes, whether in the treatment process or in the self-purification process in the stream, which are different from those created by domestic sewage. It is the interplay of three general factors —food, organisms, and environmental factors—that affects biological oxidation.

## Food

It is to be expected that the chemical composition and physical state of subdivision will affect the availability of the food. Some organic materials are more readily available than others. Sugars, for instance, are more readily available than is lignin, although both are composed of carbon, hydrogen, and oxygen. In general, as the complexity of the organic substance increases, the availability decreases. Bacteriologists have long recognized the difference in the availability of different organic compounds, and hence have made no attempt at a general mathematical formulation of the rates of biochemical oxidations. The early acceptance of a uniform rate for normal oxidation has recently been found not to apply universally for even domestic sewage, under various conditions of oxidation. The velocity constant of normal oxidation rate of 0.1 at 20° C. has been modified upward to 0.15 to 0.18 and has been found to be affected by a great number of variables, such as seeding and dilution. In view of the differences in chemical composition between domestic sewage and industrial wastes and within various wastes themselves, it is not to be expected that the rates of oxidation for domestic sewage will apply to wastes in general.

The physical state of subdivision of

* Paper of the Journal Series, N. J. Agricultural Experiment Station, Department of Sanitation, Rutgers University, New Brunswick, N. J.

the food will also affect its availability and the rate of oxidation. Microorganisms obtain their food by a process of diffusion through the cell membrane. It follows that only diffusible and soluble materials are readily available. The non-diffusible and coarse particles are converted into soluble materials by exo-cellular enzymes by a process of hydrolysis before they can be diffused into the cell and absorbed. Therefore, in wastes containing both soluble and insoluble organic materials the former fraction is oxidized first and the oxidation of the insoluble fraction is controlled by the rate at which it is hydrolyzed. It follows, further, that a waste containing only insoluble particles will be oxidized at a slower rate than one containing only soluble materials.

It is generally accepted that the rate of oxidation is independent of the quantity of organic material; that is, that a dilute material will oxidize at about the same rate as the same material in more concentrated form. This generalization is derived from deoxygenation studies with a very narrow and low range of organic matter. When sewage or waste is oxidized without any dilution in manometric apparatus the rates of oxidation are similar to those obtained by the dilution method. In the treatment of strong wastes the rate of oxidation may be affected, however, by a deficiency of oxygen created by the high demand. The question of oxygen supply is discussed more fully in connection with the environmental conditions.

The carbon-nitrogen ratio of the organic materials also affects the rate of availability. An organic material entirely devoid of nitrogen, such as sugars, is available to only a few bacteria despite its fine state of subdivision. Unless the nitrogen is present in sufficient quantities in the surrounding medium, such a substance is not oxidized. The nitrogen in the surrounding medium should be in the form of ammonia or nitrates. Organic nitrogen is first broken down, in a series of stages, to ammonia nitrogen before it becomes available for structural purposes during the oxidation of carbonaceous materials.

As the carbon-nitrogen ratio of an organic material or a waste decreases, more and more nitrogen from the breakdown of the nitrogenous portion becomes available for the oxidation of the carbonaceous portion. At a carbon-nitrogen ratio in the range of 40:1 or 50:1 there will be a deficiency of nitrogen. As the ratio is decreased further to 20:1 there will be more nitrogen than is required for assimilation into cellular protoplasm, and a slight excess of nitrogen in the form of ammonia will exist in the surrounding medium. As the ratio becomes even narrower, say 10:1, the excess of nitrogen in the surrounding medium will increase. Thus, for the rapid oxidation of carbonaceous materials sufficient nitrogen must be furnished to supply the cellular needs of microorganisms. Investigations have shown that 1 part of nitrogen will be required for every 20 parts of B.O.D.

Phosphorus also is essential for cell nutrition and oxidation of organic materials. If a waste is deficient in this element its addition accelerates the rate of oxidation. Less phosphorus than nitrogen is required (1 part of P for 75 to 100 parts of B.O.D.).

Thus, the composition and complexity of the organic matter, its state of subdivision, concentration, and the carbon-nitrogen ratio are important factors in connection with the food supply and its rate of oxidation.

## Organisms

It has been definitely established that organic materials cannot be oxidized in the absence of microorganisms. Beyond this simple general statement it becomes difficult to define clearly the importance of the numbers and types of organisms in relation to the rate of

oxidation. It must be granted that the greater the initial numbers of organisms, the shorter the lag period will be and hence the greater the over-all rate of oxidation. Compare, for instance, the time required for 90 per cent oxidation of sewage in the normal deoxygenation test, which requires 10 days, with that obtained by the activated sludge process, which requires only 6 hr. to reach the same stage. It is true that in the activated sludge process not all the impurities removed are actually oxidized. Nevertheless, as the numbers of organisms are increased, the rate of oxidation is increased to a certain point, beyond which additional organisms do not give an increase in the rate.

It is to be expected that there is also a relationship between the food concentration and the number of organisms in relation to the rate of oxidation, although such a relationship has not been clearly defined. For instance, if a certain number of bacteria or a certain amount of seed is required for a diluted material, such as in the B.O.D. technique, is it reasonable to assume that in the undiluted sewage or the waste the same rates would be obtained if the initial numbers of organisms were not increased? In established aerobic sewage treatment processes, it is felt that the numbers of organisms are sufficiently high in relation to the food so that this does not become a limiting factor in the rate of oxidation. Consider the activated sludge process with the great concentration of bacteria in the floc. Even in this process, however, experiments have shown that as the suspended solids in the mixed liquor are increased to a certain point, the rate of oxidation is increased. If this great aggregation of bacteria were not present in the floc, but instead it was attempted to obtain the same number of bacteria in a dispersed state, either greater volumes of seed would have to be returned or the rate of oxidation would suffer. A process making use of non-aggregated growths based on the above principles has been developed successfully. Here the seeding is accomplished not by flocculent growths, but by dispersed cellular material which does not form floc. By returning as little volume of seed as 25 per cent of the waste treated, 70 to 80 per cent of oxidation of impurities in the wastes has been obtained by aeration for 24 hr.

In addition to the question of numbers of organisms as such, there is the problem of types and complexity of the seed material and its effect on the rates of oxidation. Experiments have shown that the greater the complexity of the seed material, the higher is the rate of oxidation. In other words, oxidation of complex materials, such as sewage and industrial wastes, is not carried on expeditiously by a single type of organism, no matter how versatile that organism may be. Thus, treatment of industrial wastes by pure cultures of organisms, even though feasible, would not be an efficient process. (However, in industrial fermentations, such as in alcoholic fermentation or penicillin production, it is highly important to carry on the process with a single type of organism in order to get the desired end product.) Two types of bacteria working in association are thus better than one type alone, because one of them might be able to utilize the products of the other and carry on the treatment process further. As the number of types of bacteria is increased, the efficiency is also increased. The introduction of protozoa in the seed containing a great number of types of bacteria further increases the rate of oxidation. This leads to the concept of a biological community or association, and a chain of living forms. Naturally, the types of organisms within this living chain vary with the type of waste and the environmental conditions, but seldom will it be found that the organisms in-

volved belong to only one type. Those that fit into a particular chain of reactions and form a valuable link with the preceding and succeeding reactions will survive and predominate, whereas the others will either be eliminated or will be present only in insignificant numbers.

The preceding discussion on the effect of types and numbers is based on the premise that a process has been developed and has been in progress in which a successful adaptation or acclimatization of flora and fauna, orig-ally present in the waste or after its artificial introduction, has taken place.

Acclimatization and adaptation are general terms to indicate the development of an efficient flora and fauna from a mixed population suitable for a particular environmental condition and waste. All that is necessary to bring about this desired end is to have a sufficiently diversified flora and fauna in the waste. If these are lacking, it may be necessary to introduce a seeding material, such as sewage or soil suspension, which contains a diversified flora.

The second important factor in the development of a suitable seed is subjecting the waste in the presence of a suitable flora and fauna to the optimum environmental conditions for a particular process which is being developed. For instance, in the production from sewage solids of a suitable culture for sludge digestion, all that is necessary is to keep the material under anaerobic conditions with a favorable pH value; eventually the organisms originally present in the fresh solids will develop and anaerobic digestion will become established. It is not necessary to add methane-fermenting or liquefying organisms.

The terms "acclimatization" and "adaptation," however, do not clearly define the mechanism whereby a culture becomes established. The first step in this process is brought about by selection. Certain species in the mixed population find the conditions and food best suited for their development and, as a result, with continuous or repeated feeding they become the predominant forms. Initially, with only a limited number of these organisms in the inoculum, an extended lag period may be encountered, which upon repeated passages of the seed with a particular waste is curtailed, until a maximum rate possible under the prevailing conditions is attained.

The second possible mechanism in the acclimatization and adaptation phenomenon is brought about by "training." Certain species, when subjected to an unfavorable condition such as toxic materials, may be made eventually to tolerate a higher concentration of toxic materials than they could withstand initially. Certain varieties in the species may be more resistant than others to such an unfavorable condition, and may become established by a process of selection. It may also be possible to train the same organism to withstand a higher amount of toxic material by gradually increasing the concentration.

Finally, in the process of acclimatization or adaptation, a mutation may take place; the spontaneous production of a new variety or species. If the mutant is better able to withstand the environmental condition it becomes established as a result of selection.

In considering the possibility of this principle of adaptation or acclimatization in respect to certain toxic industrial wastes, it is possible within limits to develop by mutation, selection, or training, certain varieties and types which ultimately can withstand and even attack inhibiting materials, such as phenols and cyanides, which previously they were not able to withstand or utilize. The resistant or hardy varieties may have been too few initially to bring about the desired reaction. With mixed cultures it is difficult to prove whether the successful development of a culture is the result

of mutation or selection. However, examples of mutation in the bacteriological literature are numerous, such as in the production, by ultraviolet or x-rays, of new varieties of *Penicillium* capable of producing a greater amount of penicillin.

Such examples of development of new varieties may exist unknown in the waste treatment field, although no such claims have been made so far. Nevertheless, it is reasonable to assume that in the biological treatment of phenolic and other wastes containing inhibiting substances, at least a striking adaptation of the flora and fauna has taken place and the biological population in the treatment of such wastes is entirely different from that of more common organic wastes, such as those from dairies, slaughterhouses, and similar industries.

It is important, however, to bear in mind that such a process of acclimatization, training, adaptation, selection, and mutation has definite limits. In other words, it is not possible to treat wastes containing a very high concentration of a toxic material, no matter how assiduously it is attempted. There is an upper concentration of a poison that can be tolerated. Beyond that concentration, the substance will always have an inhibitory or lethal effect. The maximum concentration that can be tolerated or utilized depends on the specific compound. It is also affected by the type and concentration of the organic matter present in the substrate.

### Environmental Conditions

The effects of pH value and temperature are too well recognized among sanitary engineers to require much elaboration. It is recognized that biological processes in general, and oxidation in particular, are definitely affected by the pH value and the temperature of the substrate.

The pH value of a waste may be too low or too high initially. The oxidation rate does not seem to be so critically affected by departures from the optimum as does the anaerobic fermentation. Between pH values 6 and 8, the oxidation does not seem to be materially affected. Wider departures from these values may need correction for maximum efficiencies. Often there is a tendency for the pH value of an acid waste to rise, and of an alkaline waste to decrease as a result of treatment by an oxidation process. This natural compensation may well be made use of before any pH correction attempts are made. The acidity may be due to mineral or organic acids and carbon dioxide. Mineral acids are not attacked by bacteria, whereas many of the organic acids are utilized by bacteria. As the end product of complete oxidation is carbon dioxide, this gas may affect the pH value considerably, especially in a poorly buffered medium. Production of nitric acid by nitrification, in poorly buffered substrate or in large quantities, may affect the pH value. Whether the pH value of a waste is low initially or whether it decreases as a result of oxidation, the same retardation is obtained at equally low pH values.

The temperature coefficients during deoxygenation of diluted wastes have been carefully worked out by many investigators. It is assumed that the same coefficients apply in the treatment of the undiluted wastes. In some treatment processes, such as activated sludge and trickling filters, purification is only partly accomplished by oxidation; the remainder is due to adsorption. Because the latter is not so much affected by temperature as is oxidation, the effects of temperature on over-all purification may not be so pronounced as in deoxygenation.

The presence of an ample supply of oxygen is essential for oxidation. There is, however, a lack of clear understanding as to what constitutes an ample supply. In a homogeneous system, a trace of oxygen would theoretically be

ample if it could be maintained at all times in the entire system. In a heterogeneous system, such as in activated sludge, where the size of floc is considerable, the rate of oxygen utilization within the floc may exceed the rate at which oxygen is supplied, because of the slow rate of diffusion. A floc, therefore, bathed in a surrounding medium containing oxygen may still become anaerobic. Because the mechanism of purification resides on the surface and within the floc, such a situation may result in a deterioration of the oxidizing properties and physical characteristics of the floc. The maintenance of a higher D.O. level will increase the rate of diffusion of oxygen into the floc. Many industrial wastes have a much higher oxygen demand than sewage; therefore, the maintenance of proper oxygen level in the activated sludge process becomes more difficult, and use of this process for strong wastes becomes inadvisable. The inadequate penetration of oxygen is also demonstrated by the black coloration of a fairly thick trickling filter slime on the side next to the stone.

The effect of toxic materials may also be considered as a part of the environment. The effect of such materials originally present in the waste was discussed previously in conjunction with seeding and adaptation. There is no evidence that the oxidation is affected by the production of toxic materials during the oxidation process, aside from the unfavorable effect of carbon dioxide in lowering the pH value.

A detailed discussion of oxidation devices available for the treatment of industrial wastes would require more space than is available. In general, oxidation devices may be divided into two groups; namely, those utilizing flocculent growths and those not utilizing flocculent growths. In the first category belong activated sludge, low-rate filters, and high-rate filters. In the second category may be included sand filters and the aeration process with dispersed growths. The latter is, at present, in the laboratory experimental stage. The difference between these two groups of treatment devices consists of the relative quantities of sludge produced. In processes utilizing flocculent growths, large quantities of sludge are obtained. This is because purification is the result of adsorption and of oxidation. Not all the adsorbed material is oxidized. In addition, the sludge also increases in volume by the production of more flocculent material as a result of extensive biological growth.

The second category of treatment devices may be looked on as primarily oxidation devices whereby most of the purification is brought about by direct biological oxidation. Admittedly, in the sand filtration process, an unoxidized residue remains on and below the surface of the sand. It accumulates and has to be scraped off occasionally; ultimately it clogs the filter. However, this is due to the accumulation of the unavailable material in the waste and the growth of biological material.

In the aeration of wastes containing only dissolved and finely divided solids by dispersed growths, accumulation of large quantities of sludge is avoided by oxidizing the organic material as completely as possible in the absence of flocculent growths. The oxidation and purification is brought about by individual cells, which do not form floc particles but remain in suspension. Thus, the effluent has a turbid appearance due to the suspended cellular material. Such a process is better suited for the treatment of strong industrial wastes that cannot be readily treated by the activated sludge process. A preliminary paper dealing with some aspects of dispersed growths aeration has been published (*Industrial Engineering Chemistry*, **41**, 1412; 1949).

## Summary

An attempt has been made to give the fundamental background of biological oxidation of industrial wastes. The importance of the food factor is stressed from the standpoint of chemical composition; physical state of subdivision, concentration, and strength; and carbon-nitrogen ratio of the wastes. The second important factor is related to seeding—the number and types of organisms. Of the important environmental factors, the effects of pH value, temperature, oxygen supply, and toxic materials are briefly discussed. It is the proper juxtaposition of the food, organisms, and environmental factors that determines the successful oxidation of industrial wastes. These fundamental factors apply generally to all oxidation processes and devices, whether they be activated sludge, low-rate or high-rate filters, sand filters, or aeration by dispersed growths.


## BETTER MUNICIPAL–INDUSTRY COOPERATION NEEDED

In a paper presented at the Fifth Industrial Waste Conference, held at Purdue University, Lafayette, Ind., Nov. 29–30, 1949, W. H. Wisely, Executive Secretary of the Federation, pointed out that the record of municipal-industrial collaboration in the acceptance and handling of trade wastes in public sewage works has not been good. Some of the more apparent causes of the breakdown in such relationships were ascribed by Mr. Wisely to:

1. An unreasonable attitude on the part of the municipality with respect to the acceptance of wastes that could be handled satisfactorily.

2. Lack of proper preliminary analysis of probable effects of the industrial wastes on the public system.

3. Unrealistic preliminary analysis resulting from incomplete or inaccurate advance information on the character of the industrial operations and wastes.

4. Lack of an agreement or ordinance delineating clearly the characteristics of waste flows that are objectionable to the municipal facilities.

5. Unwillingness on the part of operation personnel at the municipal plant to make reasonable adjustments in procedures so as to accommodate certain wastes.

6. Failure of industrial management to exercise necessary control over wastes, to afford conscientious operation of pretreatment facilities, or to give prompt notice of accidental losses capable of causing upsets or damage to the municipal facilities.

7. Unwillingness on the part of the industry to bear continuing or recurring costs properly chargeable to the handling of its wastes, or to reimburse the municipality for specific damages caused by them.

8. Lack of interest and consideration by both parties for the practical problems of each other, often compounded with mutual suspicion and distrust.

# DIGESTION OF COMBINED TANNERY AND SEWAGE SLUDGE*

By Morrell Vrooman and Virgil Ehle

*Morrell Vrooman Engineers, Gloversville, N. Y.*

The City of Gloversville, N. Y., is located in Fulton County at the southern edge of the Adirondack Mountains. The 1940 census population was 23,329. The main industry of both Gloversville and Johnstown (a city of 10,700 population adjoining Gloversville on the south) is, and has been for over 100 years, the manufacture of leather gloves.

In addition to the many glove factories there are in the city 21 tanneries, which tan mostly glove leather. These tanneries also tan sheep skins and other leathers for coats, and some rabbit skins. One tannery, the largest in the city, also tans white leather for women's shoes. Most of the leather is imported from many different parts of the world.

Gloversville is located on Cayadutta Creek, a small stream flowing through the city and ultimately emptying into the Mohawk River at Fonda, at which point it has a watershed area of 64 sq. mi. The stream has a watershed area of 14.2 sq. mi. at the sewage treatment plant. The average flow is about 17.0 m.g.d.; the low dry weather flow, 5.0 m.g.d.

## Character of the Sewage

The sewage is combined domestic and tannery wastes. The tannery wastes are highly colored and contain a large percentage of solids and hair with pieces of leather and fleshings, in addition to the dirt washed from the leather and the spent chemicals used in the tanning processes. There is also a considerable amount of kerosene, solvents, grease, and oils, both from the tanning processes and from the degreasing of the hides. The sewage is highly colored at times by the aniline and other dyes used in coloring the leather.

The total combined flow of sewage received at the plant is 4½ m.g.d. for 5 days a week and 2½ m.g.d. for the remaining 2 days. The daily peak, at about 10 A.M., is 7 m.g.d. in the 5-day period. Ocasionally, during dry weather and long week-ends due to a holiday coming on Friday or Monday, the Sunday flow has been as low as 1 m.g.d.

## Condition of Cayudutta Creek

For many years the tannery wastes went directly into Cayadutta Creek and all of the tanneries were along its banks. Also, there were along the length of the creek 27 sewer outlets, which emptied sewage directly into the creek. Hence, the condition of Cayadutta Creek was bad from a pollution and odor point of view and brought about litigation by riparian owners along the creek, during the course of which 23 injunctions were granted against the City of Gloversville. Because of these injunctions, intercepting sewers were built throughout the city to collect the domestic sewage at the different outlets and also to collect all of the tannery wastes and deliver them to a sewage treatment plant. The intercepting sewer was completed in 1906 and ex-

* Presented at 1949 Spring Meeting, New York State Sewage Works Association; Kingston, N. Y.; June 6–7, 1949.

tensive experiments were carried on by the city under the direction of Morrell Vrooman, with Harry Hammon as chemist in charge of the experimental station and Harrison P. Eddy as consultant. From the experiments, which were carried on with a large-scale experimental plant for nearly 3 years, the type and design of the present plant was formulated.

The original experiments indicated:

1. That a considerable portion of the solids in the tannery wastes could be removed at the source by simple settling tanks and that more than 13 tons of solids per day could be removed by these individual tanks.

2. That combined tannery and domestic waste of the character received at the experimental plant at that time could be successfully treated by the then known methods.

3. That the plant should consist of plain bar screens, two Dortmund type settling tanks approximately 37 ft. in diameter and 50 ft. deep, a single 30-in. dosing siphon, 3 acres of trickling filters 5 ft. in depth, two secondary settling tanks 30 ft. in diameter and 30 ft. in depth, approximately 3 acres of open sludge drying beds, and 3 acres of intermittent sand filters.

4. That sludge digestion was only slightly effective and that digestion tanks were not essential.

5. That the volume of sludge was large and that the sludge would digest extremely slowly and dry on the sludge beds.

6. That because of the alkaline character of the combined wastes and because of the large amounts of alum and lime in the wastes from the tanneries, settling would be very rapid and the action similar to that of chemical precipitation.

Since the existing sewage disposal plant was constructed and put in operation in October, 1912, it has handled an average of about 6,000 cu. yd. of sludge from the sludge drying beds each year. In addition, about 5,000 cu. yd. has been removed from the separate settling tanks at the tanneries.

Because of the great increase in tannery wastes in the past 36 years and because of changes in the character of the tannery wastes due to different processes of tanning and the use of different chemicals, the treatment plant is now overloaded. The present plant is not capable of either producing a satisfactory effluent or handling the large volume of sludge. Hence, plans are being prepared for changes and additions to meet present-day conditions. Necessary to this work have been measurements of volume of sewage, both domestic and tannery; chemical analyses of all the tannery wastes; and analyses of the combined domestic and tannery wastes, including experiments in sedimentation and digestion of the combined sewage and tannery sludge.

The original plant design was based on the extensive experiment conducted during the years 1907, 1908, and 1909 and took into consideration that separate settling tanks would be built and efficiently operated at each of the tanneries to remove the readily settleable solids so as to comply with city ordinances defining maximum standards of the wastes from the tannery settling tanks that would be permitted to enter the trunk sewers or the sewage treatment plant. This worked well for a time, especially while there was rigid inspection of the tannery tanks by the city; but gradually some of the tanners gave less and less attention to the removal of sludge from their settling tanks and hence a greater load was added to the city's sewage treatment plant. This load was further increased by the increased output of the tanneries since 1912, and by the changes in methods of tanning, which detrimentally affected the operation of the sewage treatment plant.

Disposal of the raw sludge has been

the most difficult operation to be met in the several decades this plant has been operated. The excessive accumulation of sludge requires a large area for drying. Because of the slow-drying character of this sludge, the lack of any conditioning of sludge on the beds in winter weather, and finally the great amount of equipment and labor required to remove the dry or semi-dry sludge from the beds, conditions have frequently been such as to prevent sludge from being promptly removed from the sedimentation tanks. The results have been the cause of practically all operation difficulties and complaints concerning the disposal plant.

Proper operation of the plant has been upset by the accumulation of sludge in the settling tanks, reducing materially the period of sedimentation, with a consequent overflow of much solid matter to the sprinkling filters. The filters are thereby overloaded and cannot function properly.

Complaints concerning the disposal plant have been due to the odors arising from the sludge beds. The plant is maintained in an excellent condition and there are no objectionable odors around the plant. However, the main highway passes the sludge drying beds. In the public's mind, the odors arising from the decomposition of fresh sludge are associated with the disposal plant, although the beds are at some distance from the plant proper.

Therefore, if the amount of sludge is to be increased many times by bringing all tannery wastes to a central point at the disposal plant, it can be readily understood why the engineers have made every effort to overcome the condition: first, to determine if this sludge will digest; and second, to determine optimum conditions for digestion.

## Pilot Plant Studies

The pioneer pilot plant was installed during the war under the direction of R. S. Taggart, district engineer of the State Department of Health, and Willard R. Smith, operator of the plant. The pilot plant was of 375-gal. capacity, well installed, and well maintained. The sludge was taken from the sludge line in the sedimentation tanks. These tanks, two in number, were of the Dortmund type, 55 ft. deep. As the sludge line extended to the bottom, the sludge withdrawn was not strictly fresh. The sludge was seeded and the temperature of the contents of the tank was maintained at approximately 85° F. The experiments extended over a period of 7 months and the results were very encouraging. The report submitted at the end of the experiment says:

"It was found by the experiments that a large percentage of the volatile solids was converted rapidly to gas or liquid by the digestive process. This ran as high as 51 per cent of the total solids; in general, varying from 33 to 54 per cent. It was found that the sludge was quite concentrated, averaging about 16 per cent solids. It contained considerable quantities of hair and had a pronounced kerosene odor. The pH of the sludge varied with the industrial load, and was more often alkaline than acid. The variation did not adversely affect the pH of the digesting sludge, which stabilized in the pH range from 6.8 to 7.0. The volatile content of the sludge averaged nearly 64 per cent for five months. The digested sludge cracked and dried rapidly on sand drying beds. During favorable weather in June, sludge dried in from six to eight days. The quantity of gas produced on the basis of total solids was moderate. The average per capita yield was less than 0.5 cu. ft. The average yield of gas was about 5 cu. ft. per pound of volatile material destroyed. This gas burned readily."

Many experiments have been carried out at the plant with the city administration, the consulting engineer, and the operator participating. The experiments included sedimentation from several different types of tanks, preaeration, post-aeration, etc. Sludge digestion experiments were carried out

simultaneously; and as this discussion concerns this phase, the digestion experiments are taken up in detail.

Whereas the first pilot plant was installed for the purpose of proving the possibility of digesting combined tannery wastes and domestic sewage, a new pilot plant was set up for determining the rate of digestion of this sludge, as the original experiment had determined that the sludge would digest. The plant installed in 1947 consists of a 375-gal. septic tank such as used for residences (Figures 1 and 2). This is equipped with sludge inlet, sludge draw-off, four supernatant draw-offs, sludge stirring device, heating coils, and gas take-off in the top. The apparatus is heated by means of a coal stove.

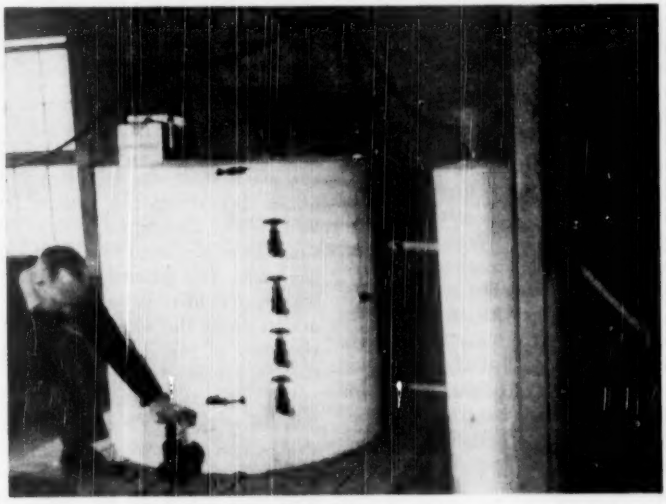

FIGURE 1.—Experimental assembly for digestion of tannery wastes with sewage.

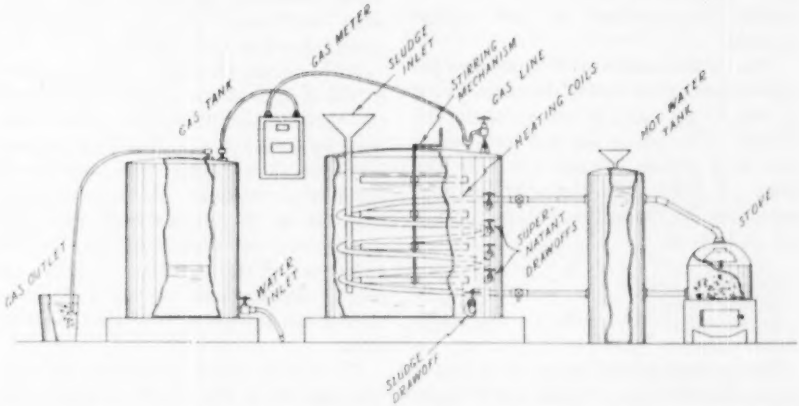


FIGURE 2.—Schematic diagram of experimental digestion assembly at Gloversville, N. Y.

The plant was started on April 21, 1947, by the addition of the proposed daily increment of sludge, 4 gal. This sludge was taken from the bottom of the sedimentation tanks and undoubtedly represented sludge partly digested. The water content was very low for sludge—namely, about 87 per cent. On May 2, 20 gal. of seed sludge was placed in the tank. From the start on April 21, to and after May 2, 4 gal. of sludge was added per day. On May 5, there was a small amount of gas, but not in sufficient quantity to measure. On May 21, the procedure was changed and the sludge then introduced into the tank was taken from 5 ft. under the surface of the sludge blanket in the settling tank instead of from the bottom, with a water content of approximately 90 per cent. This was done with the thought that such a sample would more nearly represent working conditions, with a fresher sludge. Then, too, this was the only available sludge for experimental purposes. On May 29, gas was produced in measurable quantities for the first time. From this point on the gas production was steady, averaging from 30 to 35 cu. ft. per day. The sludge taken from the lower portion of the sedimentation tank has a considerable lower pH than the material taken nearer the surface of the sludge blanket.

The volatile contents in these two instances were practically the same, being nearly 65 per cent of the solids in the sludge. The pH of the digested sludge was very stable, around 7.2. On the basis of daily tests the average temperatures for the entire 191-day period are as follows:

| | |
|---|---|
| Sludge temperature | 95° F. |
| Ingoing water | 138° F. |
| Return water | 112° F. |

The volume added to the tank was 4 g.p.d. for 46 days, 5 g.p.d. for 6 days, and 6 g.p.d. for the remainder of the experiment. Average values for the sludge were:

| Item | Raw Sludge | Dig. Sludge | Sup. Liquor |
|---|---|---|---|
| pH | 8.05 | 7.2 | 7.08 |
| Specific gravity | 1.03 | 1.062 | — |
| Solids (%) | 11.95 | 13.9 | 2.6 |
| Volatile matter (%) | 61.5 | 44.4 | — |

Average gas production was 10.3 cu. ft. per lb. of volatile matter for the entire period. Total input to October, 1947, was 1,044.5 gal., the gas production for the period being 4,875 cu. ft. The volume of the sludge was reduced 21.6 per cent during this same period.

It is of interest to note that regular gas production was recorded at the end of 40 days from the time of the first addition of sludge, or 28 days from the time the seed sludge was introduced into the tank. The quantity of seeded sludge was approximately one-half the sludge added from the sedimentation tank at the time of placing. The gas production, therefore, seemed slow in developing. It is difficult to account for this condition. The pH of the raw sludge was lower than average and the solid content was higher. Consideration was given to the fact that the sludge was taken from the deep part of the sedimentation tank and had undergone some digestion, but if such were the cases the gas production should develop more quickly.

After about 30 days, it was decided to use sludge from nearer the top of the accumulated sludge. This was done by means of a pitcher pump drawing from 5 ft. below the surface of the sludge blanket. It was thought that taking the sludge from the very upper portion would not be representative. This probably was not a correct assumption, for the solid content of the sludge withdrawn remained high.

The sludge drawn from the digester was applied to the sludge drying beds from time to time and was found to

dry rapidly, the drying period being much shorter than for the raw sludge as applied in the normal operation of the plant. In the fall of 1947, experiments were conducted by a representative of a vacuum filter manufacturer to determine if the digested sludge was filterable. It was found that this sludge could be filtered by vacuum filters, as shown in a resume of data thus obtained. Fifteen tests were made. The highest residual moisture content was 66.7 per cent, and the lowest 61.8 per cent. The chemical applied varied from no ferric chloride and 20 per cent lime to 3 per cent ferric chloride and 10 per cent lime. The optimum appeared to be about 3 per cent ferric chloride and 12 per cent lime, which was very high.

Further experiments were conducted to ascertain whether elutriation of the sludge would be of benefit. The method of washing was probably not the best standard practice, but it was proven that the rate of filtration could be stepped up and the application of the conditioning agent could be reduced. Of special interest is the fact that no lime would be required and only about 3 per cent of ferric chloride, with residual moisture in the filter cake of around 60 per cent.

The 1947 experiments demonstrated that serious consideration should be given to the problem of the digestion of this sludge. Accordingly, in 1948, preparations were made for further experiments. The experimental tank was changed in a few details where it was found from experience that it would benefit the operation; principally removing the inlet as far as possible from the point where the sludge was taken off. The first sludge was added on May 3. The quantity introduced at this time was 213 gal., of the following characteristics:

| | |
|---|---|
| pH | 7.6 |
| Specific gravity | 1.029 |
| Solids (%) | 8.4 |
| Volatile matter (%) | 63.0 |

This material was taken from about 6 ft. below the top of the sludge blanket in the existing sedimentation tanks. No seed was added, as it was felt that more information could be obtained without seed, especially as to the rate of digestion. Some gas was noticed at the end of 11 days, but this gas did not burn. At the end of 13 days a small amount of burnable gas was produced. At the end of 18 days the first measurable amount of gas appeared (25 cu. ft., the minimum measurement for the gas meter installed). On May 31, the first additional sludge was introduced into the tank and this amount, 6 gal. was added daily throughout the experiment. On June 3, the procedure was entirely changed. It was decided that the type of sludge used did not accurately represent the type of sludge that would be digested under normal operating conditions. Therefore, the experimental sedimentation tanks, with a capacity of 100 cu. ft., were used for accumulating sludge. All sludge beyond this date is fresh sludge taken in this manner. The most noticeable difference from that previously used is a somewhat higher pH (about 8.2), the lower solid content of the raw sludge (8.12 per cent), and the lower percentage of solids in the supernatant liquid (1.31 per cent). This digested sludge dried as readily as the 1947 sludge. Average sludge characteristics for this period were:

| Item | Raw Sludge | Dig. Sludge | Sup. Liquor |
|---|---|---|---|
| pH | 8.2 | 7.5 | 7.1 |
| Specific gravity | 1.023 | 1.04 | — |
| Solids (%) | 8.12 | 12.35 | 1.3 |
| Volatile matter (%) | 64.6 | 40.0 | — |

The total input from May 3 to October 21, 1948, was 1,125 gal. Gas production equalled 11.9 cu. ft. of gas per pound of volatile matter. The volume of the sludge was reduced 40 per cent. Serious consideration is being given to the use of this gas for power.

Of particular interest is the variation of pH in the unseeded material. Initial pH was 7.6 and within a few days it was slightly on the acid side, continuing on the acid side for several days and gradually working up to the point of stabilization at 8.2. Gas production became stabilized after 35 days. This point should be of interest due to the fact that no seed was added.

Experiments are being continued in 1949. As a result of the 1948 experiments, it has been decided that digestion of sludge should be included in any future planning. Also, it is the consensus that the present experiments should be carried on to determine the changes in rate of adding the daily sludge increment, and also the effects of higher and lower temperatures.

## Proposed Solution of Problem

When the original injunctions were granted in 1900, the question of policy immediately arose as to whether the city should build its intercepting sewers and sewage treatment plant to take care of domestic sewage only or the combined sewage of the city and tanneries. It was decided that the best interests of all parties concerned would be best served if the tanneries installed plain settling tanks and removed and cared for the solids that were settled out thereby. Also, that a certain effluent prescribed by a city ordinance could enter the intercepting sewers, which, with the sewage treatment plant, would be designed to take care of the very strong tannery wastes as well as the domestic sewage. Actually, the problem was and is the tannery waste with the large amount of solids and resultant sludge to be handled at the sewage treatment plant, and its effect, because of its character, on any sewage treatment process. The recent experiments indicate that the combined domestic sewage and tannery wastes can be effectively digested, with resultant benefits.

It is now proposed to treat all of the tannery wastes and domestic sewage combined, without initial treatment at the tanneries as has been required in the past, except perhaps the one limitation that solvents and the oil from degreasing of the leather be reclaimed and not permitted to enter the intercepting sewer and the treatment plant. Omitting the settling tanks at the separate tanneries and treating all of the raw wastes at the city's treatment plant was decided upon at conferences between the Tanners' Council and officials of Gloversville. This will relieve the tanners of considerable labor and cost, will improve the situation throughout the city and around the tanneries from the point of view of neatness and odor, and will release land for other uses. It will, however, put a heavier burden on the city in the capacity, design, and operation of the sewage treatment plant.

In making the measurements and calculations of the amount of sludge, a removal of 62.5 per cent has been assumed in the settling processes. This results in a daily sludge quantity of 14,770 lb. or 34,419 gal., based on a 95 per cent water content. The calculated daily domestic solids removal, based on an assumed 250 p.p.m. of suspended matter, equals 3,256 lb. The daily quantity of wet sludge equals 7,588 lb. From these figures and the other tests, analyses, and past operation of the existing plant, the desired or necessary capacity of the digestion tanks has been calculated at 305,000 cu. ft., or equivalent to a population of 105,000 people. This is based on a 5-day industrial flow of 2 m.g.d. and a 7-day domestic flow of 2½ m.g.d. It will be seen from the foregoing that this feature of the problem of the City of Gloversville is multiplied by approximately 4⅔ because of the tannery wastes. Nevertheless, this is not the whole story; because of the inhibiting character of the tannery wastes, the hair from the processes,

the leather scrap, the occasional hides, and the high color of the wastes that reach the sewage disposal plant the whole problem of treatment is made unusually difficult.

Under the new plans, it is proposed to eliminate the settling tanks at the individual tanneries and to handle the sludge at the remodeled treatment plant. In order to finance equitably the necessary new construction and the future operation of the remodeled plant, it is proposed to establish a schedule of sewer rentals.

## DISCUSSION

By W. R. Smith

*Superintendent, Sewage Treatment, Gloversville, N. Y.*

For a good many years the enormous quantity of sludge produced by the tanneries has been the main problem of sewage treatment at Gloversville. If, through lack of help, bad weather, or any other reason, it was impossible to remove enough sludge from the drying beds to keep ahead with empty ones, the sludge level in the settling tanks raised and the detention period dropped, producing more solids in the effluent. The only solution was to either provide empty drying beds or cut down on the sewage flow.

It had always been believed that Gloversville sludge would not digest, but it was finally decided to find out by experiment. Through the cooperation and assistance of R. S. Taggart, then district sanitary engineer, New York State Health Department, a sludge digestion experiment was started with two old oil barrels set up in the cellar next to the furnace—one for digestion, with a filler pipe, sludge draw-off and gas vent; the other for gas storage. Starting with seed sludge from Canajoharie, sludge was added each day from the primary settling tanks. After a time gas was being produced that would burn in a Bunsen burner and would operate a small gasoline motor for a short time. This was considered satisfactory evidence that the sludge would digest, but a lot of time and work was necessary before it could be demonstrated on a larger and better scale.

In 1942 better equipment was provided in the laboratory, as well as a better digester. The digester was a 375-gal. domestic-type septic tank with the inside removed and the top welded on. Internal heating coils were installed in the form of 96 ft. of 1-in. pipe. A 4-in. pipe running to within 1 ft. of the bottom, with a funnel on top, took care of sludge additions. Four supernatant draw-offs or sampling cocks, one 3-in. sludge draw-off, a stirring apparatus, and a gas vent to which a hose leading to the meter was attached, completed the sludge digester. A 30-gal. hot water tank and a coal stove completed the sludge heating arrangement. Both the sludge digester and the hot water tank were insulated with sheet asbestos. All apparatus was housed in an insulated building, with a partition between stove and digester. Facilities for gas storage were provided in another smaller tank. By attaching a hose to the bottom of this gas tank and applying pressure with city water it was possible to compress the gas for burning. However, with the small amount of sludge it was possible to handle in the digester (6 g.p.d.), it was impossible to put the gas to any practical use.

In 1942 the digester was run for 8 months, using sludge obtained from the bottom of the primary settling tanks. After retaining a consulting engineer to draw up plans for a new installation, however, it became neces-

sary to get the freshest sludge possible for further experiments. The first effort in this direction was to suspend garbage pails in both primary tanks, but this was unsatisfactory as it required about 20 pails and a half day's work to obtain enough sludge daily. All the pails had to be removed from the tanks and the contents resettled, decanted, and composited for the daily addition of sludge to the digester. Next was tried a metal tube of 1-gal. capacity with 12 lb. of lead in a pointed bottom, and a cover that could be removed by means of a line. The sludge in the tanks was so heavy that this sludge sampler would not penetrate it. Because of the ropes snarling when the sampler was being lowered and the cover being forced off by the heavy sludge, this method was given up before long.

Pitcher pumps with 1-in. pipes were next installed. Sludge was pumped from 5 ft. below the sludge level and it was felt that fairly fresh material was being obtained for addition to the digester.

In 1947 the digester was started with 20 gal. of seed sludge, and primary sludge secured with pitcher pumps was added daily for 7 months. After a supernatant draw-off level had been reached enough supernatant was drawn off each day to compensate for the added raw sludge, keeping the level in the digester constant. When drawing digested sludge the same procedure was followed. After the sludge was digesting properly it was possible to withdraw twice as much digested sludge as raw sludge added, by closing the gas vent to prevent air from being drawn back into the tank, drawing the sludge, and then stirring the digester contents to liberate enough gas to fill the void caused by withdrawal.

In 1948 experiments on sedimentation were conducted and a series of test tanks had been set up. The tests took so long in the laboratory that in intervals between it was possible to use the tanks for the settling of sludge to feed the digester. A day's run of sewage through the tanks obtained plenty of sludge for the digestion experiment, satisfactorily fresh and as representative as it was possible to get. In order to obtain the sludge the liquid was siphoned off, and the sludge scooped out in pails. The entire sludge content was removed and composited before the daily addition of 6 gal. was placed in the digester. To start this test 213 gal. of raw sludge was placed in the digester, with no seed sludge being used. In 11 days burnable gas was being produced. No sludge was added for 25 days from the start and the gas produced in this period measured 90 cu. ft. Then raw sludge was added at the rate of 6 g.p.d. to raise the level to a supernatant draw-off. After this level was reached the same procedure was followed as in previous tests. When raw sludge was added enough digested sludge or supernatant was drawn off to keep the level in the tank constant. This test was carried on for more than 7 months, the formation of scum being at a minimum and causing very little trouble.

In all tests it was found that the best temperature for digestion was 95° F. or above, producing gas at a higher and more uniform rate. When temperatures dropped, digestion fell off accordingly.

In this and in all previous tests the sludge (both raw and digested) and supernatant was tested daily for pH, specific gravity, moisture content, solids, and volatile matter. The temperature of both the sludge in the digester and the recirculating water was taken each day.

From the operator's viewpoint there is no question as to the method of sewage treatment to be recommended for Gloversville. Because of the large amount of solids in the tannery wastes and the difficulties in handling the resulting sludge, digestion seems to be the answer.

# THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

## DON'T OVERSELL SLUDGE

Disposal of the sludge produced in his plant is usually one of the chief headaches of any treatment plant operator. Lucky is he who can keep the entire output removed from the premises. If some return can be had, so much the better. However, preparation of sludge for sale as a balanced fertilizer requires processing that often is uneconomical to all but the largest plants. On the other hand, even the smallest plant can achieve the requirements of a "give-away" product without extra cost.

Farmers and gardeners acquainted with the advantages and limitations of sludge as a soil conditioner and fertilizer are enthusiastic repeat "customers" at many plants. Where they are, it is generally as a result of a forthright educational program wherein the limitations of sludge have been stressed sufficiently to insure its proper use and fortification for agricultural and horticultural purposes.

By contrast, high pressure selling—although such tactics may unload your entire accumulation this year—generally leaves the user feeling somewhat cheated, so that he wants no more part in the deal, even for free. In this regard, it may be well to recall the old selling maxim, "One disgruntled customer requires ten new ones to offset." It should be remembered, also, that the offer of something for nothing inherently creates distrust.

Overselling of sludge, therefore, should be assiduously avoided. Any educational program in sludge use should be just that—educational. What can be done along this line has been shown at several plants, both large and small, where demonstration flower and vegetable gardens, lawns, and orchards have been given suitable reserved publicity by the local press and radio. Many plants not only give away their filter cake or air-dried sludge, but also load it for the user, particularly if mechanical loading is feasible. At least one plant (Marion, Ind.) hauls liquid sludge in tank trucks for direct application on the land. Several others have created such a demand that the users are glad to remove sludge directly from the drying beds, thus reducing plant labor requirements for that chore (see THIS JOURNAL, July, 1949, p. 743). A note of caution should be interjected, however as regards excessive sand removal by uninstructed amateur sludge bed cleaners.

The time to plan and inaugurate your educational program is now, during the winter months, in preparation for spring sludge removal activities. It is a far cry from entertainment to sludge disposal, but one principle of the former field applies in the latter—"Don't completely satisfy 'em; leave 'em asking for more." The plant superintendent who takes the time and trouble to create an intelligent demand for his sludge usually has no further disposal problem to be solved.

H. P. O.

# SLUDGE DIGESTION TANK HEATING AND RELATED PROBLEMS—A PANEL DISCUSSION *

G. E. Symons, Chairman

*Associate Editor, Water and Sewage Works, New York, N. Y.*

*Chairman Symons:* It would be well to begin with some fundamentals of sludge heating and to define any controversial terms of statements as we proceed. The first question is: Why are digesters heated?

*P. E. Bardet, Engineer-in-Charge, 26th Ward Sewage Treatment Plant, New York City:* Digesters are heated to obtain sludge digestion temperatures most favorable to the bacterial life causing digestion.

*Chairman Symons:* What is the optimum temperature for good digestion?

*A. J. Fischer, The Dorr Company, New York, N. Y.:* In the mesophylic range, the one commonly used in practice and considered to be from 70° to about 100° F., the optimum temperature for good digestion is about 95° F. The other, or thermophylic range, is normally considered to be from 130° to 140° F.

*P. J. Cerny, Pacific Flush Tank Company, New York, N. Y.:* One comment on the mesophylic range: there are indications of an optimum temperature of 90° in one place, 95° in another. Several years ago Fair and his coworkers did some work, which developed the theory that the actual optimum temperature for any given plant depends on the rate of loading of digesters; in other words, the temperature should be coordinated with the rate of introducing the food supply into the tank—so many pounds of dry solids per cubic foot per day.

*Mr. Fischer:* I disagree. The rate of loading has nothing to do with optimum temperature.

*Chairman Symons:* It is possible to have the best digestion at a certain temperature in one plant, and at a slightly different temperature in another. In the first laboratory feeding experiments on the determination of optimum ranges, it was found that 92° was best. This temperature proved to be all right at Decatur, Ill., but other plants have found that 88° or 90° is better for their particular conditions. The optimum range is where the best over-all operation is obtained, somewhere around 90°.

*Mr. Fischer:* Probably no one will quarrel over a couple of degrees; the temperature cannot be controlled that closely. There have been cases where operation at the optimum temperature has been undesirable because of the greater scum formation, particularly where materials of a fibrous nature are present. Danbury, Conn., originally operated at 90°; at 70° to 80° there was less scum. The same thing happened at Kitchener, Ont.

*Chairman Symons:* Raising the temperature also has reduced scum formation in many cases. Each individual case is a problem in itself.

*C. C. Agar, Senior Sanitary Engineer, State Dept. of Health, Albany, N. Y.:* Can digestion temperatures be changed from one range to another?

*Mr. Fischer:* Yes. As shown by some experimental work at Jackson, Mich., there is very little lag in going from the mesophylic to the thermophylic range. If, however, it is necessary to reduce temperatures from the thermophylic to the mesophylic range, there may be a period of about a month before conditions are suitable for further digestion. With two tanks in series, the first can be run at the thermophylic range and the second at the meso-

* From transcript, 1948 Spring Meeting, New York State Sewage Works Association; Niagara Falls, N. Y.; June 4–5, 1948.

phylic, provided there is seed material in the second tank. The digestion lag in going from the thermophylic to the mesophylic range is due to the differences in the organisms involved. During mesophylic digestion there are many thermophylic organisms present, but in a dormant state. In raising the temperature from the mesophylic to the thermophylic range, most of the mesophylic organisms are destroyed. Therefore, when temperatures are lowered again considerable time elapses before digestion can again proceed.

*Chairman Symons:* That brings up the next question: How many sludge digesters be heated?

*C. R. Velzy, Consulting Engineer, New York, N. Y.:* The two basic systems of sludge heating are external and internal, depending on whether the sludge is heated before or after introduction into the digester.

*Mr. Fischer:* For internal heating of digesters there are two general types of heating coils. One depends on thermal circulation; the other, on mechanical circulation. There are also warm wall digesters, where the heating coils are imbedded in the walls or floor. Other methods consist of live steam injection into the tank, submerged combustion chambers, and immersion heaters. The heating coils may be separated into three categories —circumferential coils, vertical coils, and rotating coils. Rotating coils have not been used in the United States, but are used in Europe. One type is the regular coil about 2 to 3 ft. in diameter and 10 ft. long as used by Imhoff; the other, is mounted on a mechanism.

Hot water heating has also been used; that is, injection of hot water into the tank. It was not too satisfactory, although the "washing" of the sludge appears to be a good thing from the standpoint of improving the filtering characteristics. Subaqueous burning, as far as known, has never been used inside a digester. I can't see how it would work, because the carbon dioxide must be removed.

*Mr. Cerny:* External heating is accomplished by any of the various water-to-sludge heat exchangers; by preheating of raw sludge with live steam; by subaqueous burning, or burning gases directly in the sludge; or by immersion heaters. The water-to-sludge heat exchangers may be of the concentric pipe type or of the ordinary coil-in-tank type for preheating by hot water or hot gas.

*Chairman Symons:* The several methods of application or devices for accomplishing both basic types of heating are certainly not all equal in advantages and disadvantages. How do they compare?

*G. W. Moore, District Sanitary Engineer, State Dept. of Health, Rochester, N. Y.:* For horizontal internal coils the greatest disadvantage is one common to all methods of internal heating; the tank is not dewatered frequently enough to know what is happening to the metal. The greatest advantage is that it is the simplest method of heating digesters, both from the standpoint of design and operation. This type of coils makes full use of convection currents, being placed at the optimum location in the tank.

*Mr. Velzy:* A major disadvantage with many horizontal coils has been that the coils become loaded with sludge, which deposits at the side of the tank and doesn't flow to the center. In some cases this physical loading of the coils with solids has caused failure of the coils.

*Chairman Symons:* What about vertical internal coils?

*Mr. Fischer:* Their biggest advantage is that they can be removed from the tank for inspection and cleaning without draining the tank. In addition, they are not subject to failure by solids loading, such as previously mentioned for horizontal coils.

*Mr. Cerny:* A disadvantage common to practically all internal heating

methods is inability to control the temperature within narrow limits. For instance, when raw sludge is put into the tank there not only are cold zones in the tank contents, but also the average temperature will drop and will pick up slowly. Optimum digestion is obtained only where temperature variations are controlled within a quite narrow range.

*Mr. Bardet:* From the viewpoint of design all internal piping has another disadvantage. It is designed for the area needed and for the other factors involved, including the coefficient of heat transfer for the piping material involved. In time—and a fairly short time, at that—the coefficient changes. There is no way to make up for this variation in the coefficient.

*Chairman Symons:* What are the advantages and disadvantages of submerged burning—that is, in internal heating?

*Mr. Fischer:* An engineer, as a rule, objects to having an open flame around a digester because of explosion hazards. Therefore, as previously mentioned, subaqueous burning has not been used. Similarly, it is difficult to sell the idea of the immersion heater because of the open flame—even though the flame is confined to a pipe or other chamber—as it is argued that if the chamber burns out the open flame would operate directly in the tank, exactly as if it were a submerged combustion unit.

An interesting experience with an immersion heater was had in Mansfield, Ohio, in 1946. The idea looked attractive from the cost standpoint. However, that particular unit was near the top of the tank, so that it was partly in the scum layer, which insulated an area around the pipe coils and caused them to burn out rapidly. A similar installation at Baltimore, Md., had been operating without trouble for about a year. In that case, however, the unit was submerged about 12 ft. Also, the tank was lightly loaded, as a result of which no scum formed. In time, the coil of the Baltimore unit will probably cake up, but so far it has been successful.

The Baltimore unit consists of a central pipe, to which two U-pipes are connected. The flame is in the center pipe, the resulting hot gases passing through the two outer legs. The temperature in the unit is high enough so that no condensation is possible. In the Mansfield installation only a single U-tube was used.

At Jackson, Mich., an injector method was used to suck into the sludge hot gases formed by burning gas in a submerged combustion chamber. This is similar to the method proposed for use at Philadelphia, Pa., except that the Philadelphia unit will bring the hot gases in contact with the sludge outside of the digester. Although sludge heating was quite satisfactory at Jackson, the gases, which had to be vented, were extremely odorous—the worst I have ever smelled. I believe that at Philadelphia some provision is being made for burning these gases to destroy the odor.

*Chairman Symons:* What about radiant heating or warm wall heating?

*Mr. Cerny:* Although there aren't much operating data available for this type of installation, the literature seems to indicate certain obvious disadvantages. Coils are imbedded in the tank wall, which means that there is heat leakage. To minimize these losses the outside of the tank must be pretty thoroughly insulated. Also, there is a large number of heating coils to place in the walls, especially in heavily loaded digesters. Another problem is what to do if leaks develop in the heating coils inside the walls.

*M. M. Cohn, Editor, Sewage Works Engineering, New York, N. Y.:* If a wall crack occurred simultaneously with a failure in the radiant heating piping, it would be necessary to dig out the piping, a difficult job, or seal the concrete itself to control the leak

within the circumference of the pipe. There is considerable experience in radiant heating of buildings, and there may be some merit for its application to digesters. In one plant, a great advantage is claimed for having a radiant heated floor in the service shop while repairing a piece of equipment.

*Mr. Fischer:* To me the term "radiant heat" as applied to the warm wall digester is a misnomer. For that matter, coils imbedded in a driveway or a dwelling floor do not supply radiant heat such as is supplied by electric wall panels, which actually "shine" heat on the body.

I would like to mention another internal heating method, which in my opinion is the most efficient method of heating a digester—that is, injection of live steam into the tank contents. Its disadvantages are that if the water supply is hard it must be softened, 100 per cent make-up water is required, and water may have to be purchased because of the high quality required in the boiler. The supernatant decant is negligible, but the tank contents must be stirred as there is a tendency for the heated sludge to remain at the top of the tank. This method was successful at Jackson, Mich., but we soon found out that unless the steam was injected far enough down in the tank contents (12 ft.) it sounded like a machine gun.

*Mr. Bardet:* Mr. Fischer, using live steam heating and no stirring, found high temperatures at the top of the tank. We recently tried the same scheme at the New York 26th Ward plant and found the lower temperatures at the top of the tank. The dome plate was removed and the connections made for live steaming. No attempt was made to measure the gas, so the full efficiency of the test is not known. However, after steaming the tanks for an extended period then allowing it to rest for one day, temperatures at the top of the tank were about 88°; at the bottom, about 105°.

*Mr. Moore:* In using live steam there is always the danger that the safety devices are not working. A poorly working vacuum breaker may permit backsiphonage to foul the boiler, or perhaps crack it.

*Mr. Fischer:* Another disadvantage to be considered in steam heating is that local unions may insist on employment of a stationary engineer to operate the boiler.

*G. F. Fynn, Chief Chemist, Buffalo (N. Y.) Sewer Authority:* Quite a few years ago we injected live steam into a tank by means of a pipe. The live steam made the top sludge quite fluid, so that the pipe finally floated up from its 10- or 12-ft. depth to the surface. There was practically a condition of distillation in the tank, and when the gas pipes got pretty hot we stopped using steam.

*Chairman Symons:* That brings us to the advantages and disadvantages of the various methods of external heating.

*Mr. Fischer:* There are two large successfully operating plants on the West Coast using live steam externally, the largest being in Los Angeles County. The same disadvantages apply for applying steam heat externally as for the internal application—there must be good submergence, the boiler water must be softened, and 100 per cent make-up water must be supplied.

Subaqueous burning and immersion heaters face the same objections in external heating as in internal heating. Injection of hot gases directly into the sludge has already been mentioned in connection with internal heating.

*Chairman Symons:* The remaining methods of external sludge heating are represented by commercial heat exchangers of various types. Before discussing these, however, there is one design that should be mentioned, presented by Mr. Velzy.

*Mr. Velzy:* The design referred to

was made for the proposed Hunt's Point plant in New York City. It has not been built, and may be outmoded by the time it is built. At any rate, it is a simple concentric pipe system following the same principle as other heat exchangers now on the market. There is nothing unusual about it except that it is made of aluminum tubing to decrease weight and increase heat exchange coefficients.

*Mr. Cerny:* P.F.T. has developed and is marketing a two-pipe (concentric) heat exchanger of the type just described. There is one general comment that should be made with regard to any hot water-to-sludge heat exchanger—in the design of such a unit, provision must be made for eliminating any possibility of the heating water becoming contaminated with sludge. This is to protect the gas engines or boilers against costly damage. As experimental work has shown that welded joints are not dependable for the necessary separation, a double-gasketed joint with air gap between has been developed.

The same type of joint is used in the P.F.T. combination boiler and heat exchanger, which is applicable to the majority of installations. In this unit the inlet temperature ranges from a minimum of about 50° F. to a maximum of about 95° F., depending on whether raw sludge, digester liquor, or a mixture of the two is being heated. The outlet temperature is a few degrees higher. No adjustment of the air damper is required when switching from one fuel to the other, as the oil and gas burning rates are controlled to require the same rate of air for combustion. As far as I know this is the only dual-fuel burning equipment that is completely automatic, even to the extent of automatic preference for digester gas as the fuel.

*Mr. Bardet:* What is the sludge temperature at the outlet? Is the sludge overheated so as to maintain a fixed temperature in the digester?

*Mr. Cerny:* The sludge is overheated. As for the outlet temperature, that depends on many factors. With a unit rated at 100,000 B.t.u. per hr. and a circulation rate of 75 g.p.m. through the sludge tubes, the minimum rise would be a little over 2.5° F. With a unit rated at 1,000,000 B.t.u. per hr. and a sludge circulation rate of 150 g.p.m., the minimum rise would be a little over 13° F. These values are for heating only digester liquor at an inlet temperature of 95° F. They are predicated further on a definite temperature of heating water and a definite degree of fouling of the sludge tubes.

*Mr. Fischer:* The Dorr Company's "spiral" heat exchanger consists of two intermeshing spiral passageways. The heating medium, which may be hot water or steam, goes through one spiral. Counter-current heating is accomplished by sending the sludge through the other spiral in the opposite direction. All auxiliary elements are standard—that is, the hot water or steam boiler, the hot water circulating pump, and the sludge pump. The sludge pump handles intermediate tank liquid. There is no advantage in heating raw sludge, as it is pumped only about 1 hr. a day; therefore, to heat it to tank temperature, the heat exchanger would have to be 24 times as large as now required.

*Mr. Cerny:* We definitely recommend preheating the raw sludge, but in such a manner as to eliminate the very real objection just pointed out. For example, it is suggested that raw sludge be pumped at the lowest practicable rate, which amounts to 24-hr. continuous pumping for the larger plants and frequent and prolonged pumping periods throughout the 24 hr. for the smaller plants. The raw sludge is mixed with circulating digester liquor ahead of the heater, resulting in near optimum temperature of all material entering the digester.

This method has two decided advan-

tages. In the first place, temperature variations within the tanks are controlled to a minimum and cold zones are completely eliminated. The importance of these factors has been pointed out previously. In the second place, the food supply and the organisms responsible for the reduction of this organic material are intimately mixed and discharged simultaneously into the digesters.

The objective is to obtain the highest possible efficiency of the anaerobic sludge digestion process, thus resulting in more economical structures. This can only be accomplished by providing the means, operating procedures, and controls for maintaining an active balanced biological population. Two of the primary requirements for this condition are uniform optimum temperature and a uniform and accessible food supply.

*C. J. Velz, Head, Civil Engineering Dept., Manhattan College, New York, N. Y.:* Two different types of heaters have been described. What would be the effect of lowering the digester temperature by pumping unheated raw sludge as recommended by Mr. Fischer?

*Mr. Fischer:* The temperature difference caused by putting raw sludge into a normal digester without preheating is negligible.

*Mr. Cerny:* The temperature difference is there, but localities must be checked within the digester—local areas and zones are chilled. With increased loadings the effect becomes increasingly significant.

*Mr. Fynn:* We find considerable variation in temperature at different points. Although we have only one point of taking temperatures on a recorder, periodic observations at 2 ft. increments throughout the entire tank depth vary anywhere from 4° to 18° in zones from top to bottom. Our tanks are internally heated by circumferential coils extending from the bottom about half way up the side. The solids concentration varies from 4 to 25 per cent, with the highest value in the scum layer.

*Mr. Bardet:* There are days when we put 18,000 cu. ft. of raw sludge, or practically 10 per cent of the entire volume, into the digester. At no time has there been a drop in temperature over a 24-hr. period. If any trouble is experienced with the boiler during the winter months, the temperature may drop 1° to 1.5°.

*Mr. Cerny:* The average temperature drop depends on the ratio of the quantity of daily raw sludge addition to the volume of the digester. In the example just cited by Mr. Bardet, that drop would be almost 4°. However, the raw sludge would not be completely mixed with the entire contents of the tank, so that cold zones would exist where the temperature drop would be more than 4° average. These values are based on 200,000 cu. ft. of tank contents at 90°, and 18,000 cu. ft. per day of raw sludge at 50°. In a small tank, the application of cold raw sludge is for a short period and the effect is more pronounced.

*Chairman Symons:* The next topic is design of heating systems and related questions. The words "temperature coefficient," "heat exchange," and "transfer coefficient" have been used here interchangeably. Actually the term is "coefficient of heat transfer," and is expressed in B.t.u. per square foot per hour per degree difference in temperature. A B.t.u. is a British termal unit, or the amount of heat required to raise the temperature of 1 lb. of water 1° F.

*Mr. Velzy:* Precise detail is not necessary in heat exchange problems in sewage treatment plants. For example, the thickness of the separating medium has an influence on the coefficient of heat transfer, but the effect is not great enough to be outside the errors of the original assumptions in the case of a sludge tank wall and roof.

*Mr. Cerny:* The subject of heat exchange is relatively new to most of us

in this field and can become quite confusing if the terminology is not defined. In other discussions heat transfer rates have been quoted ranging all the way from 10 to 2,000 B.t.u. per sq. ft. per degree temperature difference. Obviously, not everyone was talking about the same thing.

The over-all coefficient of heat transfer can be defined as the rate at which heat is transferred from one medium to another per unit area of retaining wall, expressed as B.t.u. per sq. ft. per hour per Fahrenheit degree temperature difference. For tubes, the outside surface area generally is used.

Confusion often has resulted between this coefficient and the film coefficient of convection, which can be defined as the rate of heat transfer between retaining wall and fluid per degree temperature difference between the surface of the wall and the main body of the fluid. Factors affecting both these coefficients include diameter, material, and wall thickness of tubes; characteristics, velocities, and direction of flow of the liquids; and temperature range and difference of the liquids.

In designing a particular job, provision is made for additional B.t.u. demand. This represents the difference between the clean tube coefficient and the design coefficient, which involves a fouling factor that allows for deposition on both sides of the tube wall and depends on the physical and chemical characteristics of the liquids involved.

Check measurements on the units at Dayton, Ohio, after a year's operation, disclosed that the water temperature had to be increased 10° F. over the clean tube temperature to get the same output. That would presuppose cleaning of those units every 3 to 4 years and is an indication that the fouling factor used in the design is reasonable.

*Mr. Fischer:* A rapid way of figuring radiation loss is to take the sum of the areas of the tank walls, roof, and floor and allow a radiation loss of 6 B.t.u. per sq. ft. per hr. The resulting value of radiation loss is for the coldest 2 weeks in the year. This value should be added to the heat required to raise the sludge from 50° to 90° F., and the whole increased by a safety factor of 25 per cent.

*Mr. Cerny:* Another general method of computing digester radiation losses is based on correlation of observed temperature drops over a 24-hr. period for entire tank contents with the ratio between tank volume and wetted surface. This gives a mass temperature drop varying inversely with the size of the digester.

*Chairman Symons:* In two-stage digestion is heating of the second stage advisable or necessary?

*Entire Panel:* No!

*Chairman Symons:* How does the cost of an external heat exchanger system compare with internal heating coils as to installation and operation?

*Mr. Fischer:* That depends on the basis of comparison. A spiral heat exchanger would be about the same in first cost as standard internal coils for digesters about 30 to 40 ft. in diameter. The operating cost of any external heater is greater than that of internal coils, if corrosion is neglected, as there is a pumping cost to be considered with external exchangers.

*Mr. Cerny:* A mid-western plant was designed with heating coils and boiler. After bids were taken, the engineer permitted the contractor to substitute a combination heater and heat exchanger unit at no extra cost. He indicated the change effected a saving of between 10 and 15 per cent. That was a single-tank installation; in the larger plants having multiple digesters external heating has a definite advantage. In one plant, the exchangers for four large tanks are estimated to cost about the same as the heating coils for only one tank. Obviously, the cost of operation of external heat exchangers will be greater than that for internal heating coils, particularly if maintenance and other factors are ignored.

*Chairman Symons:* With internal

heating coils, at what heating water temperature will sludge cake on the coils?

*Mr. Moore:* Ordinarily, the inlet water temperature is seldom more than 140°, as a matter of safety. With higher temperatures there is a decided likelihood that caking will occur, especially above the thermophylic range.

*Mr. Fischer:* The temperature at which caking starts is indefinite. Sometimes caking takes place at low temperatures; sometimes it does not occur, even at high temperatures. After the thermophylic digestion tests at Jackson, Mich., it appeared that caking of the coils had occurred. When the tank was drained so the coils could be cleaned, it was found that gritty material piled up around the edges of the tank had practically covered the coils with gritty dead sludge, thus reducing the heat transfer. During the tests the water in the coils was heated as high as 200°. At Aurora, Ill., considerable caking occurred with heating water at 140°. Apparently, the incidence and amount of caking depends on the characteristics of the tank contents.

*Mr. Cerny:* The greatest trouble is deposition, as the coils will foul regardless of temperature. In addition, the transfer coefficient is so low that it takes a lot of fouling to reduce it appreciably.

*Mr. Velzy:* Conditions around a coil affect it more than does the heating water temperature. If the sludge is kept circulating, the water temperature can be higher without caking.

*Chairman Symons:* How can scum be kept warm, especially in winter?

*Mr. Cerny:* Insulating the top of the tank can help. Circulation of warm material so that it reaches that entire zone is also quite effective. Actually, efforts should be made toward prevention rather than cure.

*Mr. Velzy:* I'll confirm that. It is almost impossible to keep the scum layer warm in winter. The best cure is to use circulation or stirring that will actually keep the scum down and mixed with warm liquor.

*Mr. Bardet:* An electric belt around the tank was suggested at another discussion of this problem. However, because the conductivity of the scum is so poor, the belt would be ineffective. With 18-in. thick scum, the only solution was to submerge it or remove it. The best solution for wintertime scum troubles is to keep grease and scum out of the seals.

*Chairman Symons:* Is temporary heating worthwhile in starting a new digester?

*Mr. Fischer:* It is advisable never to start a digester in the wintertime. If, however, a digester must be started during the winter, the accumulated raw sludge should be transferred to the beds before digestion starts, as the tank will foam when the sludge starts to work. If the digester is started up in spring and an optimum pH is maintained, active digestion will begin without foaming.

*Chairman Symons:* Is periodic cleaning of an entire tank necessary, and if so, when?

*Mr. Fischer:* Emptying the digester at Jackson for the purpose of cleaning the heating coils was beneficial, as a tremendous volume of dead sludge was removed from the tank. The practice in the United States of using flat digester floors is poor design.

*Mr. Moore:* It is important to empty digesters periodically for inspection and cleaning. Speaking of flat bottoms, the only way to get grit from the edge of the tank to the sludge outlet is by the use of shovels and man power.

*W. R. Schreiner, District Sanitary Engineer, State Dept. of Health, Glens Falls, N. Y.:* At the Glens Falls plant sludge pumps had to be used to get the grit out of the flat digester bottom. With no suction line available they had to siphon it out.

*Mr. Velzy:* The comments on the slope of digester bottoms, particularly from the operating viewpoint, are interesting. From the construction

standpoint, bottom slopes have been kept flat as a means of convenience in building. The bottom slopes should be steeper.

*Chairman Symons:* How can internal parts of a digester become damaged?

*Mr. Moore:* One method is by electrolytic action within the digester itself; that is, there is an actual current of electricity flowing through an electrolyte (the sludge) by reason of its mineral content. Another method is by galvanic action, set up because of the proximity of dissimilar metals.

*Mr. Bardet:* A good example of galvanic corrosion was found at New York City's Coney Island plant. The contractor ran out of the material used for tank parts and appurtenances, and substituted some nuts and bolts of another material. Bolts and nuts of the main material were in perfect condition after 19 years; those of the different metal failed, dropping the parts to the bottom of the digester.

*Mr. Fischer:* Electrolytic corrosion takes place mostly on the East Coast and West Coast, where the chloride and sulfate content of the water supplies is high. Cases of corrosion are rarely found in the Middle West, where some digesters have been operating since 1926 without any evidence of corrosion. On the other hand, near the seacoast, with salt water in the area, corrosion is liable to appear in a year or less.

*Chairman Symons:* As regards the mineral content of the water, is corrosion due to low pH or to electrolytic action? Also, how would you determine which factor is the cause?

*Mr. Moore:* Normal pH—7.0 to 7.2—was found in all three tanks from which I have removed corrosion specimens. Also, the only dissimilarity between metals was found to be between different ferrous metals. A galvanometer sensitive to 0.760 microvolts showed a deflection when connected to tank metal so that an electric current definitely was present. With the tank acting as a wet cell and current flowing in the piping, it is highly probable that serious corrosion is underway.

*Mr. Schreiner:* What would be the effect of sulfates in concentration of about 400 p.p.m.?

*Mr. Fischer:* With high sulfates in fairly soft water the corrosion problems are terrific. In California many coils fail because of the rapid production of $H_2S$ by sulfate-reducing organisms. Hardness in the water apparently counteracts this effect.

*Chairman Symons:* What about the possibility of industrial wastes increasing corrosion tendencies?

*Mr. Velzy:* It is possible that industrial wastes may cause corrosion or increase the tendency to that type of deterioration. However, there seems to be no specific experience. Any waste that might cause corrosion probably should be excluded from sewage unless pretreated to correct that characteristic.

*Chairman Symons:* Are there any suggestions as to either equipment or treatment that will offset corrosion in digesters?

*Mr. Moore:* I know of no way to protect metal inside a digestion tank except by sacrificing other metal. It must be remembered that the conductivity of the supernatant is similar to that of a concentrated copper sulfate solution. Use of sacrificial plates or rods hung in the digester will save chewing up the metal parts forming one pole of the electrolytic cell. The best places to hang the sacrificial anodes can be determined by tracing the electric currents.

*Mr. Agar:* What is the patent situation regarding application of cathodic protection in sewage treatment plants?

*Mr. Fischer:* To my knowledge there is no patent on use of this method in protecting digesters—you just buy the equipment or make it.

# SEWBAZOOKA FOR HOUSE CONNECTIONS

By J. R. Jacobs

*Superintendent of Public Works, Moultrie, Ga.*

Street ditching operations frequently go below the level of existing sewers, crossing the house connections for at least one side of the street and necessitating some provision for continuation of service during the period the house sewers are broken or displaced. The problem of maintaining sewer service under these circumstances is readily solved by use of a shop-made gadget dubbed the "sewbazooka." More importantly, the apparatus keeps sewage out of the open ditch, thus avoiding contamination of the work in progress and eliminating odor complaints and unsightly conditions.

**FIGURE 1.—Telescoping sheet metal sleeves are easily fabricated.**

Essentially, the unit consists of two sheet metal tubes (Figure 1) that telescope, as shown in Figure 2, to allow for adjustment to varying conditions. Lengths and sizes for a 4-in. house sewer installation are as shown in Figure 2. All materials are 24-gauge galvanized iron, the longitudinal joints being of the crimped downspout type. The joint between the reducer end and the outer sleeve is soldered.

To use the "sewbazooka," it is telescoped and the inner sleeve is slipped over the sewer coming from the house. By extending the unit as required, the reducing end is slipped into the pipe leading to the main sewer (see Figure 3). For ordinary grades and flows leakage is prevented by the overlap of the slip joints. If, however, excessive flows or flat grades require tighter joints, packing with a little oakum or caulking compound generally will suffice.

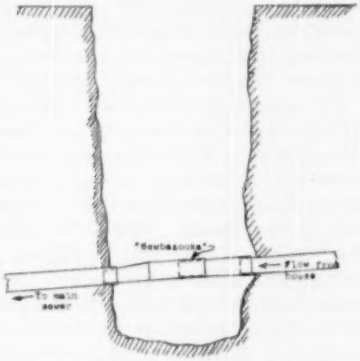


**FIGURE 3.—Method of using "sewbazooka."**

The total cost of materials and labor for fabricating the unit illustrated, which is for a 4-in. house sewer, was $3.50.

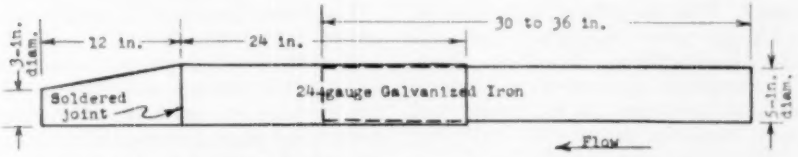


**FIGURE 2.—Details of "sewbazooka" for 4-in. house connection.**

# INTERESTING EXTRACTS FROM OPERATION REPORTS

*If at first you don't succeed, try again—then try another method*

***Attention operators!*** **It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage Works Associations, Room 325, Illinois Bldg., Champaign, Ill.**

## Report on the Operation and Maintenance of the Rochester, Mich., Sewage Treatment Plant for the Year 1948 *

By R. D. Craun, *Superintendent*

The Rochester (Mich.) sewage treatment plant was put into service in December, 1939. The construction was begun in December, 1938, as a project under the Works Progress Administration and was completed in one year at a cost of approximately $80,000.

The plant is so situated and designed that the entire sewerage system operates on gravity flow. Requirements at Rochester necessitate primary treatment only, with provision for chlorination of the effluent. Treatment facilities consist of two grit chambers, a comminutor and a bar screen, two rectangular settling tanks with straight-line sludge collectors, post chlorination equipment, a digester with a floating cover, and four uncovered drying beds. There is also a very complete laboratory provided for control purposes.

At the time of the plant construction the population of Rochester was approximately 3,500. The plant was designed on the basis of an anticipated maximum population of 6,500 in ten years. With the present population of 4,200 the plant is operating at well below design limits. The Parke, Davis Co. biological farms, which are located in close proximity to the plant site, were requested to provide treatment for their liquid wastes so provisions were incorporated in the design for treating it at the plant. This waste is received and metered separately from the Rochester sewage and a complete analysis is made and recorded so as to provide comparative data for the calculation of service charges.

When the plant was put into service it was resolved that one man would be sufficient to execute all of the operational and analytical duties. Occasional help was to be obtained from the public works department when necessary for the cleaning of drying beds, etc. The sampling and analytical routine was established at five-day intervals and this schedule was maintained until 1946. It was then believed advisable to make revisions that would make more complete and accurate data available. Therefore, sampling and analyses were established on an alternate day schedule and some revision was made in the type of data accumulated and the manner of its recording.

The basic design of the plant has proved to be very efficient, producing reductions in the suspended solids and 5-day B.O.D. that are well above average for primary treatment. The only items which caused much concern were the lack of facilities for completely dewatering the digester, the failure of

* Recipient of FSWA 1949 Hatfield Award for plants under 10,000 population.

the grit chamber drainage system, and the trapping of solids on the deflecting ledges in front of the baffles of the settling tanks.

*1948 Operation*

During 1948 the average flow was 0.481 m.g.d. This flow was composed of the sanitary sewage of the village and the liquid waste from the Parke, Davis Co. biological farms. Storm waters constitute about 20 per cent of the flow from both sources. The Parke, Davis waste, a combination of sanitary, stable, and processing waters, constituted 3.5 per cent (6.132 m.g.) of the total annual flow. Rochester contributed 169,409 m.g., or 96.5 per cent of the total. With a connected population of 4,100, this is 113 g.p.d. per capital, and on a gallonage basis, Parke, Davis has an equivalent population of approximately 150.

The over-all plant efficiency was again very satisfactory and load reductions were obtained that were well above average for primary treatment. The settleable solids were reduced an average of 94.8 per cent; the suspended solids, 66.5 per cent; and the 5-day B.O.D., 58.6 per cent. The average suspended solid loadings were: Rochester, 251 p.p.m.; Parke, Davis, 163 p.p.m. In the 5-day B.O.D. category, Rochester averaged 197 p.p.m.; Parke, Davis, 339 p.p.m.

It is interesting to note that for 1947 the Parke, Davis suspended solids averaged 330 p.p.m. and the B.O.D. was 853 p.p.m. Although the pre-settling unit had been in operation for three months during 1947 and the fact is reflected to some extent in the averages for that year, it can still be demonstrated by a comparison of the two years that the unit is very effective. The unit also has a value in its leveling effect on peak loads.

A daily average of 1,474 gal. of sludge was pumped to the digester, totaling 537,900 gal. for the year. It

**TABLE I.—Summary of 1948 Operating Data, Rochester (Mich.) Sewage Treatment Plant**

| Item | Average |
|---|---|
| Population served | 4,200 |
| Sewage treated (m.g.d.): | |
| Total | 0.481 |
| Parke, Davis (biological farm) | 0.017 |
| Rochester | 0.461 |
| Grit removed (cu. ft./day) | 16 |
| Suspended solids (p.p.m.): | |
| Raw, Rochester | 251 |
| Raw, Parke, Davis | 163 |
| Effluent | 80 |
| Reduction (%) | 67.6 |
| B.O.D. (p.p.m.): | |
| Raw, Rochester | 197 |
| Raw, Parke, Davis | 339 |
| Primary effluent | 105 |
| Chlorinated effluent | 82 |
| Reduction (%) | 59.2 |
| Chlorine: | |
| Used (lb./day) | 30 |
| In effluent (p.p.m.) | 8.2 |
| Residual after 20 min. (p.p.m.) | 0.66 |
| Raw sludge: | |
| Pumped (g.p.d.) | 1,474 |
| Total solids (%) | 4.7 |
| Volatile solids (%) | 68 |
| pH | 6.6 |
| Total solids (lb.) | 591 |
| Volatile solids (lb.) | 398 |
| Digested sludge: | |
| Pumped to drying beds (gal.) | 339 |
| Total solids (%) | 7.4 |
| Total solids (lb.) | 209 |
| Volatile solids (%) | 44 |
| Volatile solids (lb.) | 92 |
| pH | 8.0 |
| Dried sludge: | |
| From drying beds (cu. ft.) | 5 |
| Total solids (%) | 35.2 |
| Supernatant: | |
| Drawn from digester (g.p.d.) | 903 |
| Suspended solids (p.p.m.) | 3,246 |
| Gas production: | |
| Volatile solids consumed (lb.) | 248 |
| Gas produced (cu. ft.) (estimated) | 4,208 |
| Operating expenses for treatment plant and collecting system ($): | |
| Payroll | 8,671.70 |
| Power | 290.48 |
| Repairs and maintenance | 1,456.95 |
| Supplies | 1,421.34 |
| Miscellaneous | 286.86 |
| Total | 12,127.33 |
| Total cost per m.g.* | 69.09 |
| Total cost per capita * | 2.89 |

* Includes Parke, Davis wastes.

averaged 4.7 per cent solids, of which 68 per cent were volatile. This constituted a daily digester loading of 591 lb. of solids, or 398 lb. of volatile solids. Digestion produced a reduction of 62.2 per cent volatile matter, which was equivalent to 248 lb. of volatile solids destroyed per day. Unfortunately, the gas production is not metered and must be computed. As a reduction of 62 per cent of volatile is efficient digestion, 17 cu. ft. of gas per pound of volatile matter destroyed has been arbitrarily selected as a conservative estimate for the production at Rochester. Assuming this to be true, the 90,357 lb. of volatile solids digested during the year yielded 1,536,000 cu. ft. of gas, equivalent to 4,208 cu. ft. per day, or 0.99 cu. ft. per day per capita.

The operating activities were all routine, with only minor maintenance problems. The sludge collecting mechanism, which was reported as being in a very worn condition at the close of 1947, is still in service.

It was anticipated that the treatment facilities would require a minimum of time. Consequently, when planning the year's work the somewhat extraneous but desirable aspects were considered. Rather extensive concrete work was needed, and an increasing interest in the plant by the public indicated that some serious consideration should be given to it's aesthetic appeal. These two objectives were selected as the projects for the season.

Operation data for 1948 are summarized in Table I.

## Sixteenth Annual Report of the Green Bay (Wis.) Metropolitan Sewerage District for the Year Ending March 31, 1948 [1, 2]

By George Martin, *Chief Engineer and Superintendent*

The Green Bay, Wis., sewage treatment plant, providing primary treatment with separate sludge digestion and gas utilization, is unusual in that it is one of very few that are completely enclosed in a modern brick structure.

### *War Surplus Purchases*

Several times during the year advantage was taken of the opportunity to purchase, at greatly reduced prices, equipment from the War Assets Administration. Material so obtained during the year included a portable 1,500-w. generator, 2 other 1,500-w. generators, 5 portable blowers, 54 washable air filters, an electric welder, and numerous smaller items. All the equipment was needed and the cost to the District was ridiculously low.

### *Park Board Agreement*

Past practice has been to permit Green Bay City park department employees to use the District's sludge grinder. To relieve the District from any responsibility in case of accident, an agreement was reached to rent the sludge grinder for $1 per year, the park department to assume all responsibility while so using it.

### *Labor Distribution*

An examination of the labor distribution schedule, made up from daily reports submitted by each employee, discloses that 77.4 per cent of employees' time (other than administrative personnel) was devoted to only five classes of work. The greatest amount (36 per cent) was devoted to plant operation; plant repairs and mainte-

[1] For previous extracts see This Journal, **13**, 3, 587 (1941); **17**, 1, 130 (1945); and **18**, 6, 1208 (1946).

[2] Recipient of FSWA 1949 Hatfield Award for plants between 10,000 and 100,000 population.

nance consumed 24.8 per cent; laboratory was charged with 7.8 per cent; and janitor service and experimental work each required a little more than 4 per cent.

*Plant Heating*

Previously, almost the entire amount of heat required by the treatment plant was furnished by reclaiming heat from the gas engine cooling system. However, this year, due to power shortages and the District's cooperation with the power company, engine operation was changed so that both gas engines were run during the peak load periods and both units were off during low demand periods. By so operating, gas was stored during the low demand periods and utilized during the peak periods. Such procedure helped out on the power situation but materially affected the District's heat system. That is, during the periods when both engines were in operation more heat than was actually required was being produced, whereas at other periods no gas engine heat was available. Thus, the coal-fired boiler had to be operated at nearly full capacity. This required a coal expenditure of $1,622, or about four times as much as had been expended in any previous year. It should be noted, however, that the treatment plant was much better heated than it had ever been before.

*Enclosed Clarifiers*

It may be of interest to others to learn of the District's experience with enclosed clarifiers. When the first two clarifiers were built they were enclosed in a building having 13-in. solid brick walls, face brick on the outside, common brick on the inside; with steel window sash, steel roof trusses, precast Haydite roof slabs, and a steel, stucco, and glass skylight. Shortly after these units were placed in operation the paint failed, then the inside common brick started to chip and spall, the structural steel severely corroded, the steel sash deteriorated to the extent that they were replaced with glass block, and the skylight was floored over to prevent it from falling into the clarifiers. In an attempt to improve conditions the outside face of the walls was waterproofed with a transparent solution and the temperature in the building was maintained above the dew point. This year the skylight has been replaced with an all-aluminum and

**TABLE II.—Summary of 1947–48 Operating Data, Green Bay (Wis.) Metropolitan Sewerage District**

| Item | Average |
|---|---|
| Rainfall (in.) | 31.27 |
| Tributary population (estimated) | 60,000 |
| Sewage flow (m.g.d.) | 9.05 |
| Storm water by-passed, total (m.g.) | 836.36 |
| Screenings (cu. ft. daily) | 10 |
| Grit (cu. ft. daily) | 31 |
| Raw sludge, total dry solids (lb.) | 3,790,264 |
| Dry solids (lb. per day) | 11,050 |
| Volatile dry solids, total (lb.) | 2,461,669 |
| Volatile dry solids (lb. per day) | 7,177 |
| Sludge gas (cu. ft. per day): | |
| Produced | 57,233* |
| Consumed | 60,586 |
| Hydrogen sulfide in sludge gas (grains per 100 cu. ft.): | |
| Max | 91.9 |
| Min. | 13 |
| Digested sludge withdrawn: | |
| Wet sludge, total (cu. yd.) | 7,694 |
| Per cent moisture: | |
| Max | 91.9 |
| Min. | 85.8 |
| Volatile matter (%) | |
| Max. | 48.9 |
| Min. | 40.2 |
| 5-day B.O.D. (p.p.m.): | |
| Influent | 206 |
| Final effluent | 159 |
| Reduction (%) | 22.9 |
| Suspended solids (p.p.m.): | |
| Influent | 207 |
| Final effluent | 101 |
| Reduction (%) | 51.3 |
| Chlorine: | |
| Total for 5 months (lb.) | 59,370 |
| Max. p.p.m. fed | 14.8 |
| Electrical energy (kw.-hr.) | |
| Produced by plant, total | 726,662 |
| Consumed, total | 948,750 |
| Operating costs ($) | |
| Total for year | 64,912.08 |
| Per m.g. | 20.91 |

* Meter error.

glass unit and the walls, steelwork, and floor have been completely sandblasted and the entire building and equipment painted. In addition, a ventilating system and unit heaters have been installed.

A second clarifying unit was built about a year after the first one was placed in operation. To correct the shortcomings of the first unit, salt glazed tile was used to line the inside of the walls, structural steel was hot dipped galvanized, then painted, and the window sash were all of aluminum. The galvanizing and aluminum have stood up exceptionally well, but the glazed tile are spalling quite badly. Had ceramic glazed tile been used in place of the salt glazed tile the District would have had an excellent job. As it is, the glazed tile make a less serviceable wall than the common brick, which can at least be painted so that it looks good. Nothing can be done, however, to the spalling tile to preserve them and to make the walls neat appearing.

*Conclusions*

This, the thirteenth year of treatment plant operations, was quite typical. The flows, both through the plant and the storm-water bypass stations, were above the preceding year but they were by no means all time highs.

The solids actually removed this year were about 800 lb. per day more than the previous year, and in total amounted to nearly 1,900 tons (dry weight) or 51 per cent of the suspended solids carried by the sewage. This percentage of removal is about 6 per cent less than the previous year, but the records show that more sludge was removed from the clarifiers this year than last year. The difference, no doubt, is due to testing and calculating errors.

B.O.D. removals are rather low, primarily because most of the Green Bay B.O.D. load is in solution and comes from packing plants (blood), dairy waste, and other soluble food wastes.

A review of the data discloses that operations were average and about what could be expected of a primary treatment plant on a combined sewer system.

An effort has been made to gather complete laboratory data so as to determine how efficient the treatment process is and to furnish information for the design of a secondary sewage treatment plant, which is in the engineering contract stage. Come what may, the District is preparing for complete treatment, and when the day arrives the District will be ready and prepared, financially and otherwise.

Operation data for 1947–48 are summarized in Table II.

## OXYGEN ABSORPTION BY TRICKLING FILTER SPRAY

By Walter C. Anderson

*Chemist, City of Brockton Sewage Testing Laboratory, Brockton, Mass.*

Little, if any, information is available regarding the amount of oxygen absorbed by the spray from the nozzles in trickling filter operation. Therefore, when the information developed herein became available as a secondary result of another investigation, it was thought it might be of interest to other operators of trickling filter plants.

Sewage as applied to the trickling filter unit of the Brockton, Mass., treatment plant with very few exceptions contains no dissolved oxygen. In its passage through the trickling filter, however, it absorbs, on an annual average, about 6.0 p.p.m. of D.O.

To determine how much of the oxygen absorption is attributable to the

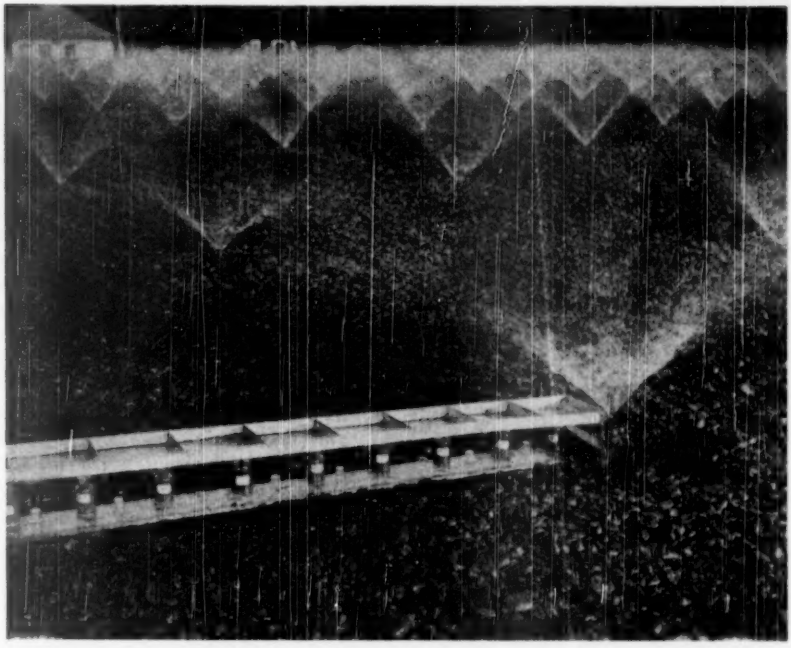

**FIGURE 1.—Special sampling tray for determining oxygen absorption by trickling filter sprays.**

nozzle spray and how much to passage through the stone, a special sampling device was employed. Made of sheet metal, the sampler is 9 ft. long (radius of nozzle spray) and 1 ft. wide (Figure 1). The collecting pan is divided into 1-ft. square sections, each of which has a drain emptying into a separate collection bottle.

During 1945 several runs of daily sampling for a period of one week were made. Typical results are given in Table I. The weekday samplings contain strong industrial wastes; the week-end samplings indicate normally weak sewage.

In 1947 another series of test runs was made, including samplings of morning (weak) sewage and of afternoon (strong) sewage for periods of one week. Table II gives a typical week's average results from this study.

**TABLE I.—Oxygen Absorption, in P.P.M., by Spray from Columbus-Type Nozzles on Standard Trickling Filters at Brockton, Mass.; Average for Week of April 24-30, 1945**

| Spray Distance from Nozzle[1] | Week-end[2] | Weekday[3] | Entire Week |
|---|---|---|---|
| 0[4] | 0.0 | 0.0 | 0.0 |
| 1 | 1.4 | 0.0 | 0.4 |
| 2 | 3.0 | 0.5 | 1.2 |
| 3 | 3.5 | 1.3 | 1.9 |
| 4 | 4.2 | 2.0 | 2.6 |
| 5 | 4.2 | 1.7 | 2.5 |
| 6 | 4.0 | 1.7 | 2.4 |
| 7 | 4.2 | 1.8 | 2.5 |
| 8 | 4.6 | 2.6 | 3.2 |
| 9 | 4.7 | 2.9 | 3.4 |
| Effluent[5] | 6.0 | 5.1 | 5.4 |

[1] Successive square-foot areas from nozzle outward.

[2] Average of Saturday and Sunday samples.

[3] Average of Monday through Friday samples

[4] Input.

[5] After passage through 9.5 ft. of filter medium.

TABLE II.—Oxygen Absorption, in P.P.M., by Spray from Columbus-Type Nozzles on Standard Trickling Filters at Brockton, Mass.; Average for Week of Oct. 15–21, 1947

| Spray Distance from Nozzle[1] | Morning[2] | Afternoon[3] |
|---|---|---|
| 0[4] | 0.0 | 0.0 |
| 1 | 0.0 | 0.0 |
| 2 | 0.7 | 0.1 |
| 3 | 1.1 | 0.1 |
| 4 | 1.4 | 0.7 |
| 5 | 2.3 | 1.1 |
| 6 | 2.2 | 1.2 |
| 7 | 2.4 | 1.2 |
| 8 | 2.6 | 1.3 |
| 9 | 3.0 | 1.4 |
| Effluent[5] | 5.2 | 4.9 |

[1] Successive square-foot areas from nozzle outward.
[2] Weak sewage.
[3] Strong sewage.
[4] Input.
[5] After passage through 9.5 ft. of filter medium.

The observed "dips" in the progressive rise of oxygen content may be accounted for by the fact that all the distributor lines on the surface of the trickling filter are dead ends, so that some settling naturally occurs in the lines. The sewage applied to the filter is settled sewage from the primary settling tanks. The rate of flow, which is regulated by a butterfly valve, is not sufficient to move the sludge settled out in the distributor lines until the valve is at least half open. The increased velocity then scours out the sludge and mixes it with the sewage, causing the dip in the oxygen content.

The results of these studies seem to indicate that there is considerable to be said for cutting down areas of the trickling filter during low night flow in order to insure maximum oxygen absorption at full spray.

## SEWER CLEANING GADGETS

By N. DeHaas

*Superintendent, Sewage Treatment Plant, Linwood, Mass.*

Simplicity of fabrication and simplicity of installation for use are two important recommendations for the sewer cleaning devices used by municipal forces in Linwood, Mass., and described here. In addition, their low cost makes their labor-saving aspects attractive even to the smallest sewer system budget.

The devices are nothing more than means of fastening pulleys in place at the top and bottom of a manhole so that rope- or cable-drawn cleaning tools may be operated in the sewer. Location of the various units is shown in Figure 1, which also shows assembly details of the three parts involved.

Spreader bar A, used at the top of the manhole, consists of a section of pipe cut to fit in the opening of a manhole frame and flattened at each end enough to give good bearing on the cover seat, thus preventing overturning. At each end of the bar a bent headless bolt with wing nut serves to fasten the bar in the manhole opening so that the pulley is positioned for pulling the cable or rope with a truck or car.

Details of spreader bar B and pin C also are shown in Figure 1. These two pieces are used to form an extensible device much like a trench jack, the nut and threaded portion of pin C acting as the screw of the jack.

In setting up at the bottom of a manhole, spreader B is placed with its strap iron feet resting at the junction of sidewall and bottom. The threaded end of pin C is then inserted in the pipe end of bar B and the whole as-

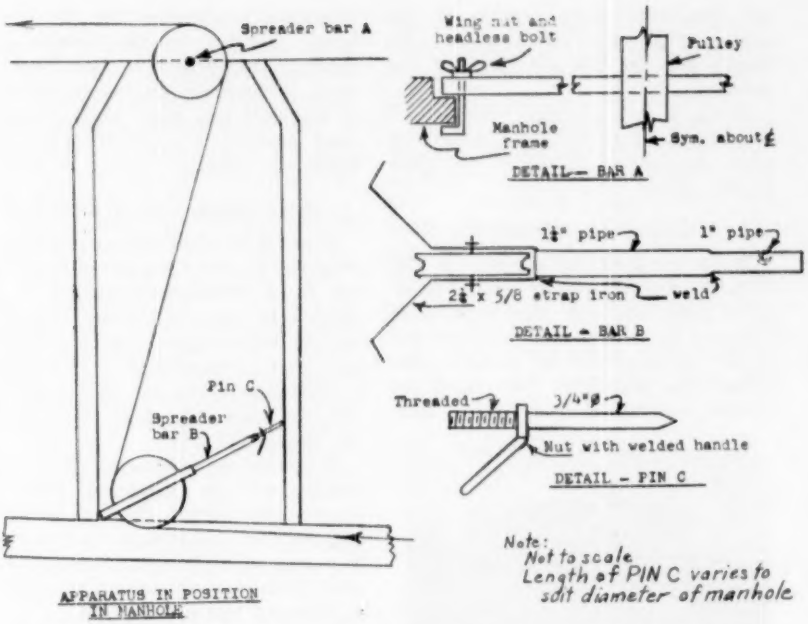


**FIGURE 1.—Details and method of using shop-made manhole pulley devices.**

sembly is adjusted until the point of pin C rests in a crack of the manhole side. Taking up on the nut then rigidly fastens the unit in place for heavy-duty use.

The assembly can be used with all the normal sewer cleaning tools operated by rope or cable, and is light enough to be carried as a permanent part of maintenance truck equipment.

## TIPS AND QUIPS

### Pickled Activated Sludge

Operations at the Gary, Ind., sewage treatment plant have demonstrated that it is possible, with proper precautions, to treat sewage carrying pickling liquor in an activated sludge plant. According to Superintendent W. W. Mathews, the conditions necessary are neutralization of the waste at the source and sufficient time interval between the source and the treatment plant so that thorough mixing, flocculation, and coagulation occurs before the pickling liquor reaches the sewage treatment plant. Results of plant operation before neutralization was started indicated that without the time interval and neutralization it would not be possible to treat this waste successfully and that it would inhibit the biological process.

At Gary, the average time for the waste to flow from source to plant is 4½ hours. This is sufficient to accomplish the needed reactions before reaching the treatment plant. Mr. Mathews stresses the time element, however, by noting that at one activated sludge plant it has been necessary to divert pickling liquor waste from the munici-

pal treatment plant because of the proximity of the source (one city block) and the low pH (1.0) of the sewage.

Seems as though this "hangover" requires the same treatment as another type—application of alkali and time to take effect!

### Center of Attraction

When the town of Ameida, in The Netherlands, planned its sewage treatment plant the new structures were designed to serve a dual purpose and to put the plant into the public's view rather than hiding it. No more noticeable location could be found than

FIGURE 1.

the center of the village square (Figure 1) where the plant, which provides sedimentation and separate digestion, is the base for the village grandstand. Although the smallest municipal sewage treatment plant in Holland, the Ameida plant certainly is not the least well known.

### Bottoms Up!

From a Florida water plant comes the report that they sell ice-cold bottled soft drinks to plant employees and visitors, using the profit to pay for subscriptions to technical magazines. Perhaps an ever better scheme is reported by another plant, where the profits from this type of enterprise are used to pay for certificates whenever any operator passes examinations.

That's certainly a worthwhile and painless method of improving plant personnel preparation for the job at hand. Besides, in later years just think of being able to look back on one's achievement in his chosen field of endeavor and know that at least a good part of it is attributable to a bottle of "coke"!

### More Head, Less Headaches

A pump problem of long standing at Auburn, Ill., has been solved by operator W. A. Rodgers, according to the May, 1949, issue of "The Windmill," news bulletin of the Central States Sewage Works Association. The pump, a centrifugal type of good manufacture, was unable to draw sludge from the final tank.

Following several attempts to get the pump back in operation after it stopped discharging, the final tank was emptied. A portable pump was used to remove as much material as possible, then the bottom accumulation of heavier material was shoveled out.

The centrifugal pump operated fairly well after the tank had been cleaned. Previous operational difficulties were attributed to the low positive head on the suction side of the pump. Had this head been greater, the heavy materials could have been removed from the final tank by the pump in the normal course of operation.

Obviously, use should be made of any extra positive head that can be made available on the suction side of a centrifugal pump, and no great dependence placed on its ability to lift unless the liquid is free from solids.

### Intentionally Fruitful

All manner of fruits, in whole or in part, seem to find their way into sewers for eventual delivery to the treatment plant. Seldom, however, does anyone deliberately throw fruit into a sewer with the intention of later recovery.

Nevertheless, that is exactly what Superintendent N. DeHaas, of Linwood, Mass., does when he has a sewer

line, particularly an inverted siphon, to clean. The fruit in this case is an orange, which Mr. DeHaas finds will float through without any trouble, carrying with it an attached string. A larger cord is then drawn through, followed by a rope or cable as needed to do the job.

Truly a case of casting one's bread on (into) the water!

### Equipment File

From "The Overflow," newsletter of the Florida Water and Sewage Works Operators Association, comes the suggestion that a complete file on all plant equipment should be on hand. The contents of such a file should include all descriptive pamphlets on each item of equipment in the plant, with parts lists, charts, and lubrication and maintenance instructions. A few minutes spent in writing for this information and fixing up a file folder for each piece of plant equipment may some day be repaid a thousand-fold when needed most. The manufacturer will gladly supply the information as to how best to use and care for his product.

Don't, however, just file the information. Use it!

### Into the Wild Blue Yonder

Earthbound, and earthy, treatment plant operators who have ambitions to rise in the world will find it easier to do just that with a new aluminum aerial platform ladder now making its appearance. Claims for the apparatus are that it offers "unlimited uses" and that it accelerates and makes easy all types of overhead maintenance, repair, inspection, and construction work.

Uniquely designed for mounting on most truck bodies, it is claimed that the unit can be used when the truck is in motion or standing in a fixed position. For transporting, the aerial ladder is retracted to half its length and lowered to a horizontal position parallel to the long axis of the truck. The extended height is 28 ft.; full rotation through 360 degrees is provided. The unit also can be used from a portable floor mounting (see Figure 2).

Manual or hydraulic actuation controls the inclination of the ladder to as much as 14 ft. laterally from the center line of the truck. This permits the working platform at the top of the ladder to reach positions over machinery and other obstructions. The guardrail around the working platform is an added safety factor.

Erection of the ladder is said to be a simple one-man operation. Required

FIGURE 2.

maintenance consists only of general lubrication.

Certainly no one need feel "tied down" when gadgets like this make it so easy to soar to greater heights!

### Clay Pipe Joint Manual

A new manual, "How to Lay and Joint Vitrified Clay Pipe," is offered free to plumbers, contractors, city officials, and others whose business requires them to keep informed on the latest practices in sewer construction.

The manual is profusely illustrated with both photographs and diagrams. It describes the approved techniques for trenching, pipe-laying, jointing, and backfilling—together with many useful methods for saving time and labor. The manual is exceptionally detailed in its discussion of up-to-date jointing procedures, including making permanent root-proof joints, speeding up setting in hot weather, pouring joints under wet conditions, pouring joints under cold weather conditions, use of primers, and cautions to be observed. Although the manual applies to sewers of all sizes, special emphasis has been given to the problems of sewers in the smaller diameters.

The manual includes considerable reference data, such as a handy table of quantities showing the amounts of jointing material required for jointing various diameters of vitrified clay pipe. It also provides a convenient listing of various sizes of clay pipe, together with all their fittings. Complete specifications, diagrams, illustrations, etc., are included.

The manual is obtainable by sending a card to the Clay Products Association, 100 North LaSalle Street, Chicago 2, Ill., requesting a copy of Bulletin 236.

### Unfair to Organized Bacteria

Recent announcement of an antibacterial cement, claimed to be usable for making concrete that actually kills bacteria and fungi on contact, leaves us sort of floundering in deep water without help in sight. The idea might be fine in the right place, but imagine the havoc that could be wrought if some of this cement accidentally found its way into the building of sewage treatment tanks. How does one go about arbitrating a walkout by either aerobes or anaerobes?

# Editorial

## WHAT'S IN A NAME?

It will be noticed that this Journal now appears under a new name, in accordance with action taken by the Board of Control at Boston on October 20, 1949. At the same time the Board initiated procedure to amend the name of the Federation itself to connote more positively its equality of interest in all waste control problems, whether they be municipal or industrial in origin.

Opinion is divided as to the true significance of these changes in names, but most are agreed that the move will serve to convince representatives of industry that the Federation stands ready to serve them. At any rate, the reaction of industrial waste technologists to the name changes appears to be highly favorable.

The important thing is that the Federation has always offered worth-while services in connection with industrial waste problems, and that these aspects have received extraordinary emphasis in recent years. Such activities have been given editorial mention in the past, but it appears appropriate here to bring them up to date:

First, industrial waste papers are now receiving more space in this Journal than are papers relating strictly to municipal sewage works problems.

Second, growing emphasis is being given in the technical programs of the Federation and its Member Associations to industrial waste papers and discussions.

Third, industrial personnel are being given increasing representation on Federation committees, and several committees are expanding their functions to afford more complete coverage of industrial problems. Notable here is the "Standard Methods" Committee, which is supervising an investment that will approach $120,000 this year in analytical methods research that is slanted strongly toward industrial waste interests.

Fourth, the new Industrial Wastes Medal of the Federation, authorized in 1949, is the first annual award recognizing meritorious technical contributions relating to industrial waste control. Only employees of industry are eligible for this award.

Fifth, the Federation continues to be the only common meeting ground for pollution control agencies, researchers, consultants, municipal authorities, and industrial representatives, who must achieve acquaintanceship and understanding if stream pollution problems are to be solved in the best interests of all concerned. Nowhere else is this possible!

The specific mention of "Industrial Wastes" in the names of the Federation and its Journal is merely the lid on the barrel. It remains for industry's representatives to help us keep the barrel full!

W. H. W.

# Proceedings of Member Associations

## PENNSYLVANIA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

**Twenty-Third Annual Meeting**

**State College, Pennsylvania, August 24–26, 1949**

The 23rd Annual Meeting of the Pennsylvania Sewage and Industrial Wastes Association was held at State College on August 24–26, 1949, in conjunction with the Pennsylvania Water Works Association. A total of 238 registered for the conference.

The topic of the opening conference session on Wednesday evening, August 24, was "The Schuylkill River Clean-Up," with J. R. Hoffert, chief engineer, Pennsylvania Department of Health, and E. S. McCawley, deputy secretary, Pennsylvania Department of Forests and Waters, presenting illustrated talks.

The main topic of the morning session on August 25 was "Philadelphia's Sewage Treatment Program." Papers by staff members of the Philadelphia Bureau of Engineering on the various phases of the program included:

"General Plan and Progress," by S. S. Baxter, assistant chief engineer of design; and

"Effects of Industrial Wastes," by H. M. Beaumont, chief, Industrial Wastes Division.

The remainder of the morning session was devoted to the Annual Business Meeting, during which amendments to the constitution were adopted to raise the dues in accordance with increased Federation activities.

An Industrial Wastes Forum and a Sewage Works Forum were conducted during the afternoon session, presided over, respectively, by Roy F. Weston, sanitary engineer, The Atlantic Refining Co., Philadelphia, and C. H. Young, division engineer, Pennsylvania Department of Health, Harrisburg. Topics presented at the Industrial Wastes Forum included:

"Pollution Effects on Stream Biology," by Ruth A. Patrick, curator of limnology, Academy of Natural Sciences, Philadelphia;

"Lime in Waste Acid Treatment," by C. J. Lewis, technical director, Warner Company, Devault;

"High Rate Anaerobic Waste Treatment," by H. W. Gehm and V. Behn, technical advisor and development engineer, respectively, National Council for Stream Improvement of the Pulp, Paper and Paperboard Industries, New York City; and

"Principles of Gravity Sedimentation and Flotation," by Professor G. A. Rohlich, University of Wisconsin.

Topics for the Sewage Works Forum included:

"Operation Practices and Experiences at Butler," by B. S. Johns, superintendent of sewage treatment, Butler;

"Starting the Abington Township Sewage Treatment Plant," by R. M. Bolenius, chemist, Abington;

"Sewage Plant Safety Measures," by Prof. R. E. Stiemke, Pennsylvania State College; and

"Aspirin for Operators' Headaches,"

by F. W. Jones, consulting engineer, Cleveland, Ohio.

At the Annual Dinner, H. E. Moses, consulting chief engineer, Pennsylvania Department of Health, presided as toastmaster. W. H. Wisely, executive secretary-editor, FSWA, spoke on "Federation Affairs." An entertainment program was followed by a short celebration of the 40th birthday of the Bureau of Sanitary Engineering, Pennsylvania Department of Health. The high hat of the Order of Sludge Shovelers was bestowed on Ruth A. Patrick, F. E. Daniels, and C. H. Young, Dr. Patrick being the first lady to have this high honor bestowed on her by the Association.

At the final session of the conference on August 26, R. E. Fuhrman, superintendent, District of Columbia sewage treatment plant, spoke on "High Capacity Filter Rates and Loadings." Three phases of "Financing Sewerage Projects" were presented, including "Engineering," by F. S. Friel, consulting engineer, Philadelphia; "Financial," by L. M. Dolphin, investment banker, Philadelphia; and "Legal," by J. Whetstone, attorney, Philadelphia.

A paper on "Sludge Disposal," by S. I. Zack, chief sanitary engineer of Gannett Fleming Corddry and Carpenter, Harrisburg, was discussed by P. O. Richter, Eimco Corp., Chicago; M. A. Clift, Nichols Engineering and Research Corp., New York City; and R. D. Nickerson, Combustion Engineering—Superheater, Inc., New York City, who spoke, respectively, on "Vacuum and Cord Filtration," "Burning," and "Drying."

The following officers were elected for 1950:

*President:* E. T. Roetman, Philadelphia.
*1st Vice-President:* John T. Campbell, Pittsburgh.
*2nd Vice-President:* H. T. Reuning, Ridgway.
*Secretary-Treasurer:* B. S. Bush, Wilkes-Barre.

BERNARD S. BUSH,
*Secretary-Treasurer*

## WEST VIRGINIA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

### Third Annual Meeting

### Wheeling, West Virginia, September 20–22, 1949

The West Virginia Sewage and Industrial Wastes Association held its Third Annual Meeting at Ogleby Park, Wheeling, W. Va., on September 20–22, 1949. A pre-meeting party was held during the evening of September 20th, where old acquaintances were renewed and new ones made.

The meeting was officially opened by President J. E. Settle on the morning of September 21st. A. H. Niles, vice-president of the Federation, presented "Greetings from the Federation."

A very interesting and informative panel was then presented entitled "Short Cuts and Ideas." This type of presentation, new to these meetings, was a series of 5-minute presentations based on the experiences of the authors. It included:

"Automatic Sampler," by D. V. Moses, technical superintendent, E. I. duPont deNemours and Company, Belle;

"Pressure Cooker Sampling Device," by A. C. Hyde, chemist, E. I. duPont deNemours and Company, Belle;

"Sampling Method for Industrial Wastes," by J. A. Sample, chief chemist, Weirton Steel Company, Weirton;

"Change in Standard Dichromate Oxidation Test," by representatives of Carbide and Carbon Chemicals Corporation, South Charleston;

"Use of Dilution Equipment for B.O.D. Test," by W. H. Swango, chemist, Carbide and Carbon Chemicals Corporation, South Charleston;

"Conversion of Refrigerator to B.O.D. Incubator," by John M. Seltzer, Kitsler Leather Company, Elkins, with discussion by J. I. Davidson, power engineer, Calco Chemical Division, American Cyanamid Company, Willow Island;

"Two-Bottle Sewage and Water Sampler," by John M. Seltzer, Kistler Leather Company, Elkins; and

"Rapid Method for Testing Acid Mine Drainage," by M. E. Hinkle, U. S. Bureau of Mines, Pittsburgh, Pa.

The first three papers in the afternoon session were a continuation of the association's long-term program planning aimed at thoroughly acquainting the membership with the basic concepts of waste treatment. These papers were:

"Use of Air in Sewage Treatment," by P. M. Thayer, engineer, Chicago, Ill.;

"High Rate Filtration," by W. Q. Kehr, engineer, Missouri State Health Department; and

"Flocculation and Sedimentation," by E. G. Kominek, Infilco Company, Chicago, Ill.

The day's program was concluded with a presentation of "Groundwork for Certification of Treatment Plant Operators in West Virginia," by R. G. McCall, engineer, W. Va. State Health Department. This paper was aimed at definite establishment of a program leading to ultimate certification in accordance with the Association's objectives.

The program on September 22 included the following informative papers:

"Treatment of Woolen Mill Wastes," by W. B. Goode, Virginia Woolen Company, Winchester, Va.;

"Effects of Pollution on the Treatment of Public Water Supplies," by John E. Tarman, director, Consulting Division, W. H. and L. D. Betz, Philadelphia, Pa.;

"Necessity for Proper Operation of Waste Treatment Plants," by A. H. Niles, engineer-supt., Division of Sewage Disposal, Toledo, Ohio; and

"Economics and Public Relations in Stream Pollution Abatement," by E. J. Cleary, executive director and chief engineer, Ohio River Valley Water Sanitation Commission, Cincinnati, Ohio.

The annual combined banquet with the West Virginia Section, American Water Works Association, was held on the same evening, with the toastmaster being L. D. Brueckel, vice-president, Weirton Steel Company, and entertainment by the Weirton Steel Male Chorus.

At the annual business meeting the following new officers were elected for 1949–50:

*President:* Edward Shroyer, Fairmont.
*1st Vice-President:* D. V. Moses, Charleston.
*2nd Vice-President:* H. W. Speiden, Morgantown.
*Secretary-Treasurer:* R. G. McCall, Charleston.
*FSWA Director:* H. D. Lyons, South Charleston.

The Association's nominee for the Arthur Bedell Award was R. G. McCall, Charleston, W. Va. The Association approved the amendment to the by-laws raising the annual dues for active members to $7.00. It also authorized the Certification and Short Course Committee to proceed with the groundwork program recommended in the paper on the program.

R. G. McCALL,
*Secretary-Treasurer*

## IOWA SEWAGE WORKS ASSOCIATION

**31st Annual Meeting**

**Des Moines, Iowa, September 20–22, 1949**

The Iowa Sewage Works Association held its 31st Annual Meeting at the Hotel Kirkwood, Des Moines, Iowa, on September 20–22, 1949. A total of 102 members and guests participated in the program with renewed interest.

The technical program consisted of papers and panel discussions. Topics covered by the papers were:

"Care and Maintenance of Electric Equipment," by C. C. Doerrie, field engineer, Westinghouse Electric Corp.;

"Operation and Maintenance of Settling Tanks," by R. G. Dagg, Chain Belt Co., Chicago;

"Research on New Developments and Maintenance of Filters," by O. F. Barklage, Infilco Corp., Chicago;

"State and Federal Stream Pollution and Other Laws Pertaining to Sanitation," by Paul Houser, director, Division of Public Health Engineering, Iowa State Department of Health, and S. C. Martin, basin engineer, Water Pollution Control Division, U. S. Public Health Service;

"Relationship Between the Engineer and the Operator," by H. H. Henningson, consulting engineer, Omaha, Nebr.;

"Financing of the Building and Maintenance of Sewage Works and Sewer Systems by Sewer Rental Method and Special Assessment," by C. D. Beh, investment banker, Des Moines;

"Iowa State College Extension Service Educational Program for Sewage Works Personnel," by W. E. Galligan, professor of civil and sanitary engineering, Iowa State College; and

"New Developments in Sludge Digester Heating," by Don Walker, president, Walker Process Equipment Co., Aurora, Ill.

In addition, films were shown on safety, electricity, and waste treatment.

During the afternoon session on September 20, a visit was made to the Iowa Pipe and Tile Company's Des Moines plant, where the processes of producing clay sewer pipe were shown and explained.

An innovation in informal group discussion procedures was well received in an "Over the Coffee" program on the morning of September 21. At this session separate tables were devoted to groups from each type of plant and the discussions were very lively. Leaders were state department of health district engineers. Coffee was served during the session, for which the allotted two hours proved insufficient.

On the morning of September 22 an "Operators Breakfast," led by F. R. Martin, Marshalltown; Guy Burton, Iowa Falls; C. M. Bergstresser, Oskaloosa; and W. E. Galligan, Ames, was well attended. Again, the allotted two hours proved insufficient for the lively discussion.

Evening activities on both September 20 and 21 were preceded by a clubroom hour sponsored by the Water and Sewage Works Manufacturer's Association.

The Annual Banquet on September 21 featured brief comments on "The Importance of Sanitation," by H. Ross, mayor of Des Moines; a historical summary of Association activities by J. Hinman; and an entertaining talk by G. E. Symons, associate editor, *Water and Sewage Works*, New York City.

At the Annual Business Meeting it was voted to increase the annual dues

to $8.00, effective January 1, 1950. The following officers were elected for 1949–50:

*President:* Paul Bolton, Des Moines.
*Vice-President:* Carl Borland, Mason City.
*FSWA Director:* P. J. Houser, Des Moines.
*Secretary-Treasurer:* Leo Holtkamp, Webster City.

LEO HOLTKAMP,
*Secretary-Treasurer*

## MEMBER ASSOCIATION MEETINGS

| *Association* | *Place* | *Time* |
|---|---|---|
| New York State Sewage Works Association | Hotel Statler, New York, N. Y. | Jan. 20–21, 1950 |
| Texas Water and Sewage Works Association | Texas A. & M., College Station, Tex. | Mar. 12–16, 1950 |
| New Jersey Sewage Works Association | Stacy-Trent Hotel, Trenton, N. J. | Mar. 22–24, 1950 |
| Virginia Industrial Wastes and Sewage Works Association | George Washington Hotel, Winchester, Va. | Mar. 30–31, 1950 |
| Arizona Sewage and Water Works Association | Safford, Ariz. | Mar. 31–Apr. 2, 1950 |
| Arkansas Water and Sewage Conference | Robinson Memorial Auditorium, Little Rock, Ark. | Apr. 17–19, 1950 |
| Kansas Sewage Works Association | Lamar Hotel, Salina, Kans. | Apr. 20–21, 1950 |
| Montana Sewage Works Association | Florence Hotel, Missoula, Mont. | Apr. 20, 1950 |
| California Sewage Works Association | Lafayette Hotel, Long Beach, Calif. | May 3–6, 1950 |
| Pacific Northwest Sewage Works Association | Winthrop Hotel, Tacoma, Wash. | May 10, 1950 |
| Michigan Sewage Works Association | Park Place Hotel, Traverse City, Mich. | May 22–24, 1950 |
| Alabama Water and Sewage Association | Alabama Polytechnic Institute, Auburn, Ala. | June 6–8, 1950 |
| Central States Sewage Works Association | Indianapolis, Ind. | June 9–10, 1950 |
| Ohio Sewage and Industrial Wastes Treatment Conference | Gibson Hotel, Cincinnati, Ohio | June 28–30, 1950 |
| Pennsylvania Sewage and Industrial Wastes Association | Pennsylvania State College, State College, Pa. | Aug. 23–25, 1950 |
| Iowa Sewage Works Association | Hotel Blackhawk, Davenport, Ia. | Sept. 19–21, 1950 |
| Rocky Mountain Sewage Works Association | La Fonda Hotel, Santa Fe, N. Mex. | Sept. 27–29, 1950 |
| Missouri Water and Sewerage Conference | Sheraton Hotel, St. Louis, Mo. | Oct. 1–3, 1950 |
| **Federation of Sewage Works Associations** | **Hotel Statler, Washington, D. C.** | **Oct. 9–12, 1950** |
| North Carolina Sewage Works Association | Washington-Duke Hotel, Durham, N. C. | Nov. 13–15, 1950 |

# Federation Affairs

## RECORD REGISTRATION AT TWENTY-SECOND ANNUAL MEETING

Besides being an outstanding meeting by virtue of the scope and quality of both the technical papers and the social events, the 22nd Annual Meeting of the Federation, held at Boston, October 17–20, 1949, drew 821 registrations, the largest number ever recorded at a Federation meeting. The previous high total registration mark, 812, had been established at the Toronto meeting in 1946.

Extremely gratifying was the large attendance of industrial waste treatment personnel, whose numbers helped to swell the men's registration figure to a record 679, upsetting the old mark of 637 set at Detroit in 1948. Ladies attending the meeting numbered 145, the second largest figure to date.

Great credit is due the host New England Sewage Works Association, the Convention Management Committee, and the Local Arrangements Committee, headed by E. Sherman Chase, for the careful and efficient manner in which the meeting was planned and managed. The smoothness and precision with which the various meeting functions progressed resulted from the careful and painstaking attention to detail by the various local committees.

Representation at the 1949 meeting was geographically well distributed, with every section of the United States and Canada represented, as well as visitors from India, England, and Australia.

The 22nd Annual Meeting was convened at 10:00 A.M. on Monday, October 17, 1949, by President V. M. Ehlers. After reviewing Federation accomplishments during the preceding year, President Ehlers briefly outlined his hopes for continuing and new Federation activity in the year to come. Following presentation of the Executive Secretary-Editor's report by W. H. Wisely, which concluded the business part of the opening session, President Walter H. Brown, Jr., welcomed the meeting on behalf of the host New England Association.

### Technical Program

The technical program developed by the Program Committee, under the chairmanship of F. W. Gilcreas, presented papers of both quality and diversity of subjects in keeping with the excellent standard of Federation meetings. Topics of broad interest were included, as well as many on specific pollution and waste treatment problems. An Industrial Wastes Forum, developed around topics of interest to industrial representatives, was extremely well attended by that group and further established the worth of the Federation's activities in this direction. Attendance at this and the concurrent and always popular Operators' Forum was about equal. Indicative of the interest aroused in both sessions were the spirited discussions from the floor.

The technical program presented at Boston was the same as that announced in the Annual Meeting Preview carried in the September, 1949, JOURNAL on pages 931–934, with the exception that the paper on "Sewage Treatment and Disposal for Boston," originally scheduled to be presented by R. P.

Shea, was actually presented by John F. Flaherty, senior civil engineer, Sewer Division, Boston Public Works Department. All technical program papers will be published in 1950 issues of the JOURNAL.

### Entertainment Events

The social program was opened on Monday evening, October 17, by an informal reception for Federation and the host New England association officers and wives. Following the reception, an extremely interesting lecture by Bradford Washburn, Director of the Boston Museum, was enjoyed by an estimated 650 members and guests. Illustrating his story with colored slides and moving pictures, Dr. Washburn entertainingly and informatively described "Operation White Tower," a scientific expedition to the top of Mt. McKinley.

The Federation luncheon Tuesday noon was attended by 350 persons. President Ehlers presided and presented the featured speaker, Gordon M. Fair, Dean of the Graduate School of Engineering, Harvard University. Dean Fair, speaking on "Sanitary Engineering in a Changing World," briefly outlined sanitary engineering developments to date as a basis for projecting a prediction for the quarter century just ahead and offering the challenge of making the next 25 years as productive of advance as the last 25.

The Annual Federation Dinner and Dance, held in the Imperial Ball Room Wednesday evening, October 19, was the really outstanding social event of the meeting. At the dinner, presided over by President V. M. Ehlers, the 492 members and guests present were delightfully entertained by the singing of Mr. and Mrs. Jess L. Russell, of Union City, Tenn., and a "barber-shop" quartet led by Karl R. Kennison, chief engineer, Construction Division, Metropolitan District Commission, Boston. President Ehler's presentation of the annual Federation awards concluded the dinner program. Dancing followed.

### Ladies' Entertainment

The excellent series of social events planned by the local Ladies' Entertainment Committee, under the chairmanship of Mrs. T. A. Berrigan, was immensely enjoyed by the large group of ladies attending the meeting. The gracious spirit of hospitality and friendliness with which committee members welcomed the visiting ladies was deeply appreciated.

Those ladies who arrived on Sunday before the meeting opened were taken to the world-famous Toll House Inn at Wayland, Mass., for luncheon. Afterward the party drove to Plymouth, Mass., site of the Pilgrim landing in 1620, to visit Plymouth Rock and the restoration of the original Plymouth Village.

The Monday "get-acquainted" tea provided an excellent opportunity for all to greet old acquaintances and meet new ones. The motor tour of historic Boston and Charlestown on Tuesday morning, in the course of which many of the Revolutionary and pre-Revolutionary shrines of the area were visited, proved a delightful experience to all. The Boston Museum tour on Tuesday afternoon was enjoyed by a large group, who were particularly intrigued by the excellent displays of glassware, chinaware, and tapestries.

A bus tour through the lovely varicolored fall foliage of the eastern Massachusetts countryside on Wednesday morning took the ladies to the Lexington-Concord area to visit the site of the opening battle of the Revolution, and then on to the Wayside Inn at South Sudbury for luncheon. The afternoon was spent in browsing through the Inn proper and through the nearby restorations of the Grist Mill, the Mary Lamb Schoolhouse, the Martha-Mary Chapel, and the inn grounds and coach house. The day's activities were climaxed by return to

the convention hotel for the Federation Dinner and Dance.

### Men's Inspection Trip

The men's inspection trip, included in the technical program on Wednesday afternoon, attracted so many that the group was divided into two sections. One section visited the William T. Sedgwick Laboratories of Sanitary Science at Massachusetts Institute of Technology. The other section visited the waste treatment plant handling fatty acids and soaps from waste soap manufacturing waters at the Proctor and Gamble Company's Quincy, Mass., factory by controlled pH and finely divided air to float out the suspensions and floc formations for recovery and reprocessing. Both groups then met at the Metropolitan District Commission's new Nut Island sewage treatment plant.

### Manufacturers' Exhibit

Those attending the convention gave a great deal of attention to the interesting and informative display of equipment and suppliers' products arranged by the Water and Sewage Works Manufacturers' Association. All of the 50 booth spaces available were utilized by the 29 manufacturers and suppliers represented.

### Annual New England Dinner

The New England Sewage Works Association, host to the Federation meeting, held its deferred 20th Annual Dinner on Tuesday evening, October 18, at Northeastern University. This gala event was attended by almost 200 members and guests. At a brief business meeting following the dinner, the Association amended its by-laws to increase the dues. Federation President V. M. Ehlers conveyed the Federation's official expression of gratitude and appreciation for the excellent manner in which the NESWA had carried out its responsibilities as host to the 22nd Annual Meeting. An interesting illustrated travelogue of his recent tour of Europe was then presented by E. Sherman Chase.

Officers elected by the NESWA for the year 1949–50 were:

*President:* Ralph W. Horne, Boston.
*1st Vice-President:* William S. Wise, Hartford, Conn.
*2nd Vice-President:* E. Sherman Chase, Boston.
*Secretary-Treasurer:* Walter E. Merrill, Boston.

## BOARD OF CONTROL ACTIONS AT BOSTON

A heavy agenda, including several matters of more than ordinary importance, was given attention by the Federation Board of Control in the business sessions held at Boston on October 16 and 20 in connection with the Twenty-second Annual Meeting. The sessions were attended by 35 officers and Directors, together with 5 proxy holders.

The October 16 session occupied the entire day, and was devoted largely to reports of officers and committees. Upon its adjournment the Election Committee named the following officers to serve during the year 1949–50:

*President:* Arthur H. Niles, Toledo, Ohio.
*Vice-President:* Ralph E. Fuhrman, Washington, D. C.
*Treasurer:* W. W. DeBerard, Chicago, Ill.

Richard H. Gould, New York City, was elected to serve a 3-year term as Director-at-Large.

President V. M. Ehlers relinquished his office to President-elect Niles at the organization meeting of the 1950 Board of Control on October 20. A number of noteworthy actions were taken by the new Board.

### Changes Initiated in Names of Federation and Journal

In recognition of the equality of the Federation's interest and activity in problems of stream pollution caused by industrial wastes as well as municipal sewage, the JOURNAL was renamed "SEWAGE AND INDUSTRIAL WASTES" effective with the commencement of monthly publication in January, 1950. Action was also taken to initiate an amendment of the constitution that would change the name of the Federation to "Federation of Sewage and Industrial Wastes Associations" at the next meeting of the Board. If the Constitution and By-laws Committee so desires, however, it may submit alternate recommendations for the revised name, but it is definitely intended that a change will be adopted in 1950.

### New Industrial Wastes Award

Creation of an Industrial Wastes Award, to be given for noteworthy contributions to the JOURNAL, further demonstrates the determination of the Board to emphasize attention to industrial wastes problems. The new annual award will be in the form of an attractive plaque; it may be won only by an industrial employee whose published paper is adjudged by the Awards Committee as the most outstanding contribution on industrial wastes control to appear in the JOURNAL during the stated year.

The first of these awards will be made in 1950, based on papers contained in the 1949 volume of the JOURNAL.

### By-Laws Amendments

Two amendments to the Federation By-laws were adopted at Boston. One of these involved abolishment of the General Policy Committee, which has had no clearly delineated functions since the early years of the 1941 reorganization. The other amendment removed the restriction that has heretofore prevented a member of the Board from being nominated for Honorary membership.

### New Manuals Authorized

The Board authorized publication of the manuals of practice on "Chlorination of Sewage" and "Air Diffusion in Sewage Works," subject to their clearance by the Sewage Works Practice and Publications Committees. Both reports are in a late stage of preparation, and should be possible of production in 1950. Distribution will be by sale only.

### 1949 Awards

The following annual awards were conferred by the Board and presented by President Ehlers in the course of the Twenty-second Annual Meeting:

*Harrison Prescott Eddy Medal*—To John W. Hood for his paper "Measurement and Control of Sewage Treatment Process Efficiency by Oxidation-Reduction Potential."

*George Bradley Gascoigne Medal*—To Wilbur N. Torpey, for his paper "Practical Results of Step Aeration."

*Charles Alvin Emerson Medal*—To William John Orchard, for his many years of devoted service to the Federation from its inception to the present.

*Arthur Sidney Bedell Awards* (for service to Member Associations)—To Frederick Leon McDonald (Arkansas), Walter Asa Sperry (Central States), Harold Warner Streeter (Federal), R. Paul Farrell (Kentucky-Tenessee), Willard F. Shephard (Michigan), Harry P. Croft (New Jersey), William McKinney Piatt (North Carolina), Carl Edwin Green (Pacific Northwest), and Victor Marcus Ehlers (Texas).

*William D. Hatfield Awards* (for outstanding sewage works operation reports)—To Russell D. Craun of Rochester, Minn., and George W. Martin of Green Bay, Wis. A "previous

winner's" award was also granted to Thomas T. Hay of Racine, Wis.

There were no nominations this year for Honorary membership.

### Membership

In his detailed report to the Board, the Secretary noted the admission into the Federation of the Sewage Works Section of the Louisiana Conference on Water Supply and Sewerage, bringing the total of Member Associations to 35. An application for admission was received during the Boston convention from the Sewage Works Section of the South Carolina Water and Sewage Works Association, and this was approved in the October 20 session.

As of September 30, 1949, the Secretary reported the aggregate Active and Corporate membership of all Member Associations to be 5,119.

### Committee Functions

Twenty-one committee reports were heard by the Board on October 16, several of them including developments of special interest.

The Sewage Works Practice Committee noted the production of the accounting and sewer ordinance manuals in 1949, and reported progress in the preparation of seven others. Reference is made above to the authorization given for publication of the manuals on chlorination and air diffusion.

Continuation of the analytical methods research project under grants made by the National Institutes of Health was reported by the Committee on Standard Methods for Sewage and Industrial Wastes Analysis. Results of this work will be available for the tenth edition of "Standard Methods," which is now in the early planning stage.

The Committee on Sewage Works Nomenclature, having consummated its duties with respect to the "Glossary—Water and Sewage Control Engineering," was discharged by the Board with commendation for its fine work.

Again denoting its concern with industrial waste interests, the Board instructed the Committee on Operators' Qualifications to review its 1945 report with a view toward its applicability to operators of industrial waste treatment works.

The Research Committee described its important investigation of toxic wastes, which is now being conducted by three subcommittees. The studies include reviews of the literature, assembly of bibliographies, and laboratory research; some findings are expected to be ready for publication during 1950.

### 1952 Meeting in New York

The Board voted to hold the Twenty-fifth (Silver Anniversary) Annual Meeting of the Federation in New York City, in October, 1952. With the 1950 and 1951 annual meetings scheduled for Washington, D. C., and St. Paul, Minn., respectively, these plans are laid well in advance.

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## A. H. NILES ASSUMES FSWA PRESIDENCY

Arthur H. Niles of Toledo, Ohio, became the tenth President of the Federation at the 1949 Annual Meeting of the Board of Control at Boston, October 20, 1949.

Following his early education in the public schools of Hill Top, Ark., and Grayling and Ann Arbor, Mich., Mr. Niles graduated from the University of Michigan in 1916, receiving the B.S. degree in Civil Engineering. Summer vacations from school had been spent working on construction jobs, and doing surveying and appraisal work for various railroads and public utilities.

Following graduation from the University of Michigan, Mr. Niles was engaged on construction of a hydro-electric installation on the Manistee River at Wellston, Mich., until he entered the Army in May, 1917. Having completed the course at the First Officers Training Camp, he was commissioned as 2nd Lieutenant in the Engineer Officers Reserve Corps and served 19 months in France with the 101st (Combat) Engineers, 26th Division, which took part in 5 major engagements.

From 1919 to 1924, Mr. Niles was engaged successively as assistant city engineer of Jackson, Mich.; assistant city engineer of Lansing, Mich.; and city engineer of Sturgis, Mich. In 1924 he was employed by the Philip Carey Co. of Cincinnati, Ohio, as sales promotion engineer, becoming manager of the Columbus, Ohio, branch in 1926.

In 1928 Mr. Niles joined with A. H. Smith of Toledo, Ohio, to form the consulting engineering concern of A. H. Smith and Niles Co. During the ensuing four years the firm gained an excellent and wide experience in design and supervision of construction of sewers, sewage treatment works, water systems, water treatment plants, and industrial plants, and made numerous reports on water and sewage problems.

In 1932, when the City of Toledo was ordered to start operating its new sewage treatment plant, completed the previous year, Mr. Niles was engaged to initiate operation. Within a short time he was put in charge of the Division of Sewage Disposal as Engineer-Manager, which post he still holds. In addition, Mr. Niles is technical supervisor for the operation of several municipal sewage treatment plants and an industrial waste treatment plant, as well as acting in an advisory capacity on several industrial waste investigations and treatment problems.

In 1937 Mr. Niles helped form the Northwest Ohio Sewage Conference, and served as president of this first sectional or area conference primarily intended for small plant operators. He also served two successive terms as president of the Ohio Conference on Sewage Treatment. In addition, besides many other committee assignments, he represented the Conference on the 8-man committee charged with working out all details for the short school for water and sewage plant operators, initiated in 1948.

Mr. Niles has served on the Federation Board of Control as Director-at-Large (1941–44) and as Director from the Ohio Conference (1946–48). As a member of the Sewage Works Practice Committee he made significant contributions through the sub-committees concerned with producing the Federation's Manuals of Practice on "Utilization of Sewage Sludge as Fertilizer" and "Municipal Sewer Ordinances." He also was a member of the General Policy Committee.

During his term as Vice-President (1948-49) Mr. Niles was a member of the Executive Committee and the Meeting Place Committee. He has been a member of the Quarter Century Operators Club since 1946.

Mr. Niles' long and varied experience in all phases of sewage and industrial waste works gives him a particularly sensitive understanding of the varied problems facing the Federation membership. His service and proven leadership will greatly help the Federations' progress toward achieving its goal of expanded service in 1950.

## R. E. FUHRMAN NEW FEDERATION VICE-PRESIDENT

In his capacity as Superintendent of the District of Columbia Sewage Treatment Plant, Vice-President Ralph E. Fuhrman brings to the Federation

leadership a practical understanding and appreciation of the problems facing both municipal and industrial waste treatment personnel, as well as proven administrative and technical abilities.

Mr. Fuhrman's activity in Federation affairs is indicative, not only of these abilities, but also of his interest in the well-being and progress of the Federation. As a member of the Board of Control, first as Director from the Missouri Water and Sewage Conference (1932 and 1934–37) and then as Director from the Maryland-Delaware Water and Sewerage Association (1946–48), he served on the Membership (1934–37), War Service (1943–44), General Policy (1942–49), and Legal Analysis (1943–44) Committees. He is at present a member of the Executive and Meeting Place Committees.

Having been a sanitary engineer with the Missouri State Board of Health before going to the District of Columbia as Assistant Superintendent of Sewage Treatment in 1937, Mr. Fuhrman has seen the practical aspects of operation from both the operating and regulatory viewpoints. His member association activities have been progressively valuable, first to the Missouri Conference, and then to the Maryland-Delaware and Federal Associations.

Mr. Fuhrman brings to his new Federation position a wealth of experience, tempered with sympathetic understanding of the problems confronting operating, regulatory, designing, and legal personnel, as well as a first-hand working knowledge of member association activities. His proven administrative abilities and his sincere enthusiasm should point the way to continuing progress of the Federation towards its goal of service to the field of pollution abatement.

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## REVISED RULES FOR OPERATION REPORT COMPETITION

Among other actions, the 1949 Board of Control in session at Boston again adopted revised rules for the William D. Hatfield Awards, which are made annually for outstanding waste treatment plant operation reports.

The rules which now govern the William D. Hatfield Awards are as follows:

### A. Purpose of Awards

The purpose of the William D. Hatfield awards is to encourage operators of sewage and waste treatment plants to prepare, publish and distribute annual operating reports which are necessary or desirable for the following purposes:

1. To serve the interests of public relations.

2. To provide a means whereby the operator may make a businesslike accounting of the expenditure of funds and care of the treatment plant and accessories entrusted to him.

3. To serve the report requirements of the operator's superior officials.

4. To serve generally as a basis for recommendations made by the operator for improvements to his plant to secure better efficiency and economy of operation of higher degrees of treatment.

5. To advance the art and knowledge of sewage and waste treatment through making available to other engineers and operators the basic information and data concerning operation of a particular plant which is needed for study or appraisal purposes as related to proposed new developments or changes in operating procedures or methods elsewhere.

### B. Number of Awards Which May be Granted Each Year

A William D. Hatfield Award may be granted each year upon recommendation of the Operation Reports Committee and approval by the Board of Control to an operator in each of the following categories who previously has not been the recipient of such award and who is adjudged to have submitted the best annual report

on plant operation, judged in accordance with the schedule presented herein.

1. Operators of plants serving less than 10,000 population or population equivalent.
2. Operators of plants serving 10,000 to 100,000 population or population equivalent.
3. Operators of plants serving more than 100,000 or population equivalent.

Operators of industrial waste treatment plants as well as operators of municipal sewage treatment plants are encouraged to compete.

In addition to the above, a William D. Hatfield Award, to be designated as a previous winner's award, may be granted to any operator in each of the above categories, who previously has been the recipient of such an award and whose report is adjudged to be the best in comparison with other reports submitted by previous winners of the award.

### C. Procedure For Submitting Reports

To enter the competition during any year:

1. The annual operating report must be printed, mimeographed, or typewritten, and must cover a period of 12 months of operation beginning with some month within 27 months immediately preceding July first of the year for which the award may be granted. (That is, reports eligible for the 1950 award will probably cover 12 consecutive months of operation within the period April 1, 1948 and March 31, 1950.)
2. Five (5) copies of the report must be submitted by the competing operator to the Secretary of the Federation of Sewage Works Associations not later than June 1 of the year in which the competition is entered. No entries will be considered which are received later than June first.

### D. Procedure for Routing Reports To Operation Reports Committee

1. Upon receipt of above 5 copies of report from any competing operator, the Secretary of the FSWA shall transmit one copy thereof to each member of the Operation Reports Committee for rating in accordance with the schedule presented herein.
2. Prior to September 1 of each year, each member of the Operation Reports Committee shall send to the Chairman of said committee the ratings of the reports made by such committee member. The ratings shall be given in percentages for all reports entered in each of the three categories specified in Section B above.
3. Upon receipt of the ratings reported by individual members of the Operation Reports Committee the Chairman shall add thereto his own ratings. The final rating of any report shall be determined by taking the average ratings for such reports as made by all members of the Committee. In each category the reports achieving the highest average rating as made by the several members of the Committee shall be adjudged to be the winning report in such category.
4. In case of a tie, duplicate awards will be made.
5. No award will be made to any operator who achieves a final rating of less than 70 per cent on his report.

### E. Rating Schedule

Judging of reports shall be in accordance with the following schedule:

| Item | Maximum Percentage Points |
|---|---|
| 1. If report is printed or duplicated by mimeograph, etc. | 5 |
| 2. General format of report—appearance, attractiveness, binding, use of illustrations such as charts or photographs | 10 |
| 3. Contents or text of report, covering the following items: | |
| a. Introduction giving purpose and some historical background of plant | 5 |
| b. Description of treatment works | 10 |
| c. Pertinent data concerning design and actual loadings of plant | 10 |
| d. First cost and operation cost data | 10 |
| e. Plant performance based upon analytical and other records | 15 |
| f. Evaluation of operating data | 5 |
| g. Effects of effluent on receiving waters | 5 |
| h. Statement of operating problems | 5 |
| i. Statement re: research training activities or public relation matters | 3 |
| j. Maintenance program | 5 |
| k. Conclusions or recommendations | 10 |
| Total | 100 |

## OHIO AND ALABAMA ASSOCIATIONS WIN MEMBERSHIP CONTESTS

The 1949 Federation membership contests, carrying prizes of $100 each for the greatest numerical gain and greatest percentage increase, were won by the Ohio Sewage and Industrial Wastes Treatment Conference and the Sewage Works Section of the Alabama Water and Sewage Association, respectively. Both contests covered the year ended September 30, 1949.

In increasing its enrolled membership by 78 during the year, the Ohio Conference far outstripped runners-up in the numerical increase race. Honorable mention in this category, with the gains recorded, goes to California (57), Iowa (43), Michigan (39), and the Institute of Sewage Purification (31).

An outstanding 220 per cent won the percentage increase prize for the Alabama Association, which only has been affiliated with the Federation since June, 1948. Other leaders in this contest were Iowa (60 per cent), Arkansas (41 per cent), and Ohio (33 per cent).

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## LOUISIANA AND SOUTH CAROLINA ASSOCIATIONS AFFILIATED WITH FEDERATION

Admission of two new sewage works sections during 1949 brings to a new high the number of member associations affiliated with the Federation.

The Sewage Works Section of the Louisiana Conference on Water Supply and Sewerage became the 35th member association on March 5, 1949, when it adopted a revised constitution. Previous action by the Federation's Board of Control had approved the Section's petition for affiliation, subject to the constitutional revision. For the Louisiana Conference, Joseph Cefalu is Chairman, Ben S. Graves is Vice-Chairman, S. S. Crawford is Federation Director, and Dan L. Winters is Secretary-Treasurer.

Approval of the petition for affiliation of the Sewage Section of the South Carolina Water and Sewage Works Association by the Federation Board of Control at the Boston meeting, October 20, 1949, made the Section the 36th member association. The action in this case was effective immediately, as the necessary constitutional revisions had already been adopted. Officers of the South Carolina Association are: J. W. Logan, President; A. M. Johnstone, Vice-President; and W. T. Linton, Secretary-Treasurer.

The inclusion of Louisiana and South Carolina within the territorial coverage of member associations leaves only Mississippi in the South, Nebraska in the Middle West, and Nevada and Utah in the Rocky Mountain area without official Federation representation. Sanitary and industrial wastes personnel in these states are served, however, by member associations in adjacent areas.

# Reviews and Abstracts*

**An Investigation and Study by the Department of Public Health of the Causes Creating a Nuisance on the Shore and Beaches of Swampscott and of Means of Rectifying Such Conditions.** Report of the Department of Public Health, Massachusetts. (Dec., 1948).

This report describes conditions on the 16.2-mi. shore line from Nahant to Marblehead, north of Boston. Domestic sewage (22.7 m.g.d.) from the city of Lynn and the towns of Swampscott, Nahant, and Marblehead is discharged into tidal waters, which are deep, except at Nahant. Adequate screening should suffice. At Swampscott, however, from 0.8 to 7 m.g.d. of sewage is discharged, after comminution, through an outlet in 46.5 ft. of water. Materials characteristic of sewage pass through the comminutors and strand on nearby beaches. The Swampscott beaches are also affected by coal dust from Lynn. On other beaches, deposits of a marine growth known as *Ectocarpus* occur, which dries and gives off a strong putrid odor.

The seven active beaches have a total shore length of 6.4 miles, which are used on an average by 15,000 bathers, with a maximum of 147,000. The resident population of the four municipalities was 131,908 (1945 census). Lynn is sewered in part on the combined system and in part on the separate system. Nahant, Swampscott, and Marblehead have separate systems. The bar screens at Lynn and Marblehead have 1¼- and 2-in. openings, respectively. More effective screens were recommended. Along the shores grease balls were noted, and condoms.

The bacteriological examinations of the Department have shown that the waters were safe for bathing, the recent geometric mean Coliform Index (organisms per 100 c.c.) ranging from 19.3 to 268.3 on various beaches, with an average for seven beaches of 124.7.

The general recommendations are that more floating materials be removed; coal dust be controlled; screening equipment be improved; and that private sewer outlets be eliminated in certain areas.

LANGDON PEARSE

**The Determination of the Type and Degree of Treatment Required for an Industrial Waste Problem.** By PHILIP F. MORGAN. *Proceedings* of the Third Industrial Waste Conference, pp. 74–84, Purdue University (1947).

A discussion of the research program relating to a solution of the problem of deinking wastes as particularly related to the Kalamazoo (Mich.) region. The program included: (1) studies of all possible methods of treatment so that deinking mills in various parts of the country could select the most economical type of treatment for their particular requirements, and (2) studies of the effect of deinking waste on streams to make possible the prediction of degree of improvement of polluted conditions obtainable in any given stream for the various methods of waste treatment that could be used.

The studies involved data on B.O.D. and solids removals which could be obtained by plain sedimentation, chemical precipitation, and other methods of physical separation such as heat coagulation, centrifugal separation, and filtration.

Studies at the Kalamazoo mills were made in an effort to segregate and/or reduce the volume of wastes. The effect of the deinking wastes on the river was also required. The critical section of the river was between Comstock and Otsego, Mich.

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in THIS JOURNAL. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage Works Assns., 325 Illinois Bldg., Champaign, Ill.

A cooperative plan was worked out between the Michigan Stream Control Commission and the National Council for Stream Improvement. The former inspected some 160 industrial plants in the vicinity of Kalamazoo, and a detailed check of the waste flow in 13 paper mills on the critical section of the river was divided between the two groups. The domestic load from the cities of Kalamazoo, Parchment, Plainwell, and Otsego was estimated on the basis of current populations.

The discharge to the river of B.O.D. and suspended solids was as follows:

| Vicinity of | Pounds Per Day B.O.D. | Susp. Solids |
|---|---|---|
| Kalamazoo | 73,584 | 252,380 |
| Plainwell | 6,652 | 21,244 |
| Otsego | 13,257 | 17,586 |

Thirteen sampling stations were set up in the river between Comstock and Williams Bridge, a distance of 34.5 miles. Fortnightly surveys were carried on throughout the summer. Each survey consisted of four separate traverses of the 13 sampling stations, with separate traverses spaced at 6- to 8-hr. intervals. During one week all of the paper mills were shut down for vacation so that the effect of this shut-down could be seen on the D.O. and B.O.D. of the river water.

From these data deoxygenation and reoxygenation coefficients for the Kalamazoo River will be determined. The data will also make possible the computation of the allowable load on the river, as compared with present loads, to determine the percentage of load reduction required to satisfactorially solve the pollution problem in Kalamazoo.

H. Gladys Swope

**The Treatment of Cyanide Waste by Chlorination.** By John G. Dobson. *Proceedings* of the Third Industrial Waste Conference, pp. 209–227, Purdue University (1947).

Free cyanide is a very toxic substance, 0.1 p.p.m. having been fatal to fish under some conditions. From 0.1 to 0.3 gm. of CN is fatal to humans. Cyanide interferes with both aerobic and anaerobic sewage treatment processes, and if the sewage is chlorinated noxious gases may be produced.

The methods proposed for treating cyanide wastes have been acidification and removal of the resulting HCN gas by air blowing, reaction with "lime sulfur," aeration, reaction with ferrous sulfate, oxidation with potassium permanganate, and oxidation with chlorine.

Sources of cyanide wastes include plating of metal parts, case-hardening of steel, neutralization of acid "pickle scum," refining of gold and silver ores, and scrubbing of blast-furnace and producer-gas-furnace gases. In metal plating the wastes result from the dilute solutions of the various plating baths, except occasionally when the entire bath is dumped. In the nitriding of steel, the steel is immersed at a predetermined temperature in a molten bath consisting of a mixture of sodium cyanide, barium chloride, sodium chloride, potassium chloride, and strontium carbonate. The discharge from a bath of this sort may run as high as 50 to 100 p.p.m. of free cyanide. There is also the problem of disposing of the spent salt baths

In order to remove mill scale in the pickling of steel sheet, the metal is usually dipped in dilute sulfuric and hydrochloric acid, and a "pickle smut," which is not soluble in the acid, is deposited on the steel. The "smut" is removed by agitating the steel in a solution containing sodium cyanide and sodium hydroxide (0.2 oz. per gal. of each). The wastes from such a process are the wash waters and the cyanide-neutralizing baths themselves—together these may carry 200 to 1,000 p.p.m. of CN.

The oxidation of cyanide with chlorine is discussed. To convert cyanide to cyanate the pH must be above 8.5. If this pH is maintained, no CN has been found in the presence of free available chlorine as measured by the orthotolidine arsenite test.

A survey of the several states was made regarding permissible concentrations of cyanide allowed to discharge to watercourses. Of the 31 states replying, the regulations, if any, varied, but most were of the general opinion that no cyanide should be discharged.

Two schematic diagrams are shown for the treatment of cyanide wastes, and one diagram for a cyanide-chromium waste treatment plant. It is suggested that recovery of metals is possible if the value of

the metals offsets the cost of recovery. A discussion of possible analytical methods for the determination of cyanide is given. It is pointed out that the cyanide determination is difficult.

H. GLADYS SWOPE

**How to Control Psychoda Flies in Sewage Treatment Plants.** By JOHN W. HOOD. *The American City*, **64**, 136 (May, 1949).

At Ridgewood, N. J., it has been found that DDT and BHC (benzenehexachloride) will eliminate the type of flies found there, each product being effective against a certain type of fly. The filters cover an area of 0.6 acre and are 5½ ft. deep, with a basalt medium. Flooding had been used to control flies, but this method was not satisfactory as the efficiency of the filter was impaired.

Use of DDT in a concentration of 12 p.p.m. at the nozzles over a 2-hr. period gave control that was effective for 20 days. Hand spraying of exposed wall surfaces and marginal areas of the medium completed the control. Application in concentrations of one-half this dosage was ineffective.

In 1947 DDT gave good control until mid-August. At that time a different fly put in an appearance. It was found that DDT was effective when *P. albipunctatus* predominated. When *P. alternata* predominated, DDT failed to function.

Various compounds were used unsuccessfully until BHC E=9 was tried. Results of the first test were inconclusive because of a severe thunderstorm which broke just as the test started. In the next test the dosing tank, filter, and final clarifier were taken out of service and a volume of 25,000 gal. left in them for recirculation. To this was added 15 gal. of BHC E-11 and 2 gal. of emulsifier. The mixture was then pumped back for 12 hr. This resulted in the entire area of the beds being dosed once per hour, yielding a 10-min. application time and a 50-min. rest or contact period, and a 600 p.p.m. (or 0.06 per cent) BHC E-11 concentration.

This method was entirely satisfactory without marginal spraying. The initial treatment yielded 28-day control. In the next treatment 10 gal. were used and 2-month control was realized.

T. L. HERRICK

**Treatment and Disposal of Waste Waters from Processing of Coffee.** By T. W. BRANDON. *East African Agricultural Journal*, **14**, No. 4 (Apr., 1949).

Mixed waste waters produced during processing of coffee are equivalent in polluting character to about 60,000 gal. (Imp.) of crude domestic sewage for each ton of clean coffee produced. About 85 per cent of the total polluting matter is produced during pulping, and 15 per cent during washing of the fermented beans.

The most polluting liquids are, in order: tank effluent, first tank washings, and pulp water.

By rapid separation of pulp from conveying water, 40 per cent of the pollution contributed by pulp water can be avoided. This is equivalent to nearly 20 per cent of the total polluting matter from all sources.

Laboratory experiments indicate that the polluting character of the mixed waste waters, or of pulp water alone, can be greatly reduced by natural fermentation, but difficulties might arise in operating this method at a factory.

The B.O.D. of the mixed waste waters was reduced by up to 50 per cent by treatment with chemical coagulants, but it was concluded that addition of coagulants would not be a suitable means of treatment, owing to the close control required and difficulties involved in disposal of sludge.

Experiments suggest that the most satisfactory method of treatment would be by biological filtration. The installation required to reduce the total polluting character by 94 per cent, at a factory producing 1 ton of clean coffee per day, would cost about £1,850.

In deciding which means of treatment is to be adopted, consideration should be given to local conditions, such as the degree of dilution available in the river to which the effluent is discharged and the requirements of other riparian owners. In deciding what size of plant is required, reference should be made to the production of clean coffee at each factory over a period of several years.

Provided the effluent is of reasonably good quality, it seems unlikely that use of filter effluent for factory operations would have any harmful effects on the quality of the coffee.

H. P. ORLAND

**Mechanical Flocculation in Sewage Purification.** By John Hurley and W. F. Lester. *The Surveyor*, **108**, 339 (June 3, 1949).

Observations have been made on the performance of tanks equipped for mechanical flocculation and sedimentation at the Coven Heath works of the Wolverhampton Corporation. Part of the tanks provide plain sedimentation only, so such a comparison is possible. It is concluded "that it seems fair to say that the Clariflocculator effluent is about 20 per cent better than that from the ordinary clarifier."

Laboratory scale tests made at the Barnhurst sewage works on the flocculation of filter effluents have shown promising results. Good reductions in B.O.D. and suspended solids were realized in many cases. Tests along this line are being continued and it is hoped that results from large scale tests will be available at a later date.

T. L. Herrick

**Report of the Government Institute for Sewage and Waste Treatment (The Netherlands) Covering the Years 1938–1947.** By C. P. Mom. 127 pp. (1949).

Because of the war and several other circumstances, it was impossible during the period covered to publish the customary annual reports of the institute. The present report covers 10 years of work in a condensed form. In 1946, H. Kessener, well known for his development and research work, resigned. The report is divided into four sections, dealing with stream pollution studies; advice to governmental agencies; development and design of treatment works for municipalities, industries, and military and civil agencies; and various investigations and studies pertaining to the operations of treatment plants.

The institute has a far broader scope than is customarily covered by state and federal agencies in this country. In addition to studying stream pollution and determining the need for sewage and waste treatment, plans, specifications, and cost estimates are prepared and advice is given to municipalities and industries, thereby taking a considerable part of the functions performed by consulting engineers in this country, but the functions are of a purely advisory nature and cannot be inforced if the advice is not followed. The work connected with the operation of treatment plants falls in the same category.

Studies of a considerable number of streams, lakes, ponds, and canals showed that, in general, industrial pollution was as important as or of greater mangitude than domestic sewage pollution. In sections of the northern part of the country dairies were mainly responsible for excessive pollution, whereas in other sections in the north potato starch manufactory causes very undesirable conditions. In the northeastern part of the country textile industries discharge waste insufficiently treated, resulting in odors, killing of fish, etc. In the center part of the country municipal sewage is mainly responsible, whereas in the southwest flax retting causes pollution of the receiving waters. In the south, mine drainage and culm adds to the pollution of streams which receive sugar beet wastes discharged in Belgium and chemical wastes in Germany. In order to improve matters as soon as possible, this area has been divided into five districts, each requiring considerable sums of money to alleviate the undesirable conditions.

Many reports were made to various agencies and municipalities regarding treatment requirements for wastes from textile, laundry, canneries, paper, leather, tanneries, potato starch, soap manufactory, paint and dye, etc., leading to a general statement which sounds familiar: "Too frequently no attention is paid to the location of industries in relation to disposal of wastes, especially when no municipal sewage system is available. This results in the necessity of erecting complete purification systems at very high costs."

**FIGURE 1.—Division tower at Enschede, Holland.**

A considerable number of plans and specifications were prepared and plants constructed. The treatment works varied from the construction of fish ponds, through primary treatment, to complete treatment by activated sludge. Some of the structures are of general interest. For instance, the division tower at the municipal sewage treatment plant at Enschede (Figure 1), where a dry weather flow of 12 m.g.d. and a maximum flow of 36 m.g.d. is treated, is different from the usual type of division chamber for the trickling filters. At this place the screened sewage is preaerated for 22 min. by the use of rotating brushes, settled, and then treated on 12 rotary filters, again settled, and the final effluent retained in a pond for final purification. When the flow is greater than three times the dry weather flow, the excess sewage passes through the pond. Supernatant liquor from the heated separate digestion tanks is returned to the influent.

**FIGURE 2.—Settling tanks for paper mill waste.**

Settling of paper waste in Dortmund tanks built above ground (Figure 2) provides for removal of fiber from the waste of a paper mill. The report contains a number of tables showing the efficiencies of the various installations.

W. RUDOLFS

**Surveying and Monitoring of Radiation from Radioisotopes.** BY G. W. MORGAN. *Nucleonics*, **4**, 3, 24 (1949).

Survey instruments and techniques for personnel safety in handling radioactive materials are explained. Tables are presented to indicate the "strength" of beta and gamma radiations in air. Thus, beta particles of 0.1, 1.0, and 2.0 mev. have a maximum range of 0.11, 3.7, and 8.4 meters of air, respectively. Shielding by containers or barriers equivalent in mass thickness to the mass of air may be used to compute the shielding necessary to eliminate beta exposure or limit the dosage rate. The dosage rate at 1 ft. from a gamma ray emitter of 0.1, 1.0, and 2.0 mev. is 0.5, 6.0, and 10.0 milliroentgens per hour per millicurie, respectively, assuming one photon per dissintegration. (One millicurie is defined as $3.7 \times 10^7$ disintegrating atoms per second.) Applying the inverse-square law, the dosage rate from a 2-mev. gamma ray would be 40 mr. per hr. per millicurie at 0.5 ft., or 2.5 mr. per hr. per millicurie at 2 ft. from the point source.

The permissible exposure ranges, in centimeters from a point source of gamma radiation, are calculated for various mev. energies and millicurie quantities, assuming a permissible exposure of 6.25 mr. per hour. The permissible range for a 1-mev. gamma source would be 21 cm. for 0.5 millicure, 30 cm. for 1 mc., 95 cm. for 10 mc., and 300 cm. for 100 mc. The permissible exposure of 6.25 mr. per hour is a derived value presumably based on the new revised maximum permissible exposure of 300 mr. per week and an 8-hr. 6-day week. Calculated values are useful in planning an experiment, but survey instruments and personnel monitoring meters should be used to measure the field of radiation. Arbitrarily, the limit above which a radiation survey is required during the course of an experiment is 50 to 300 microcuries. A bibliography and general reference list is appended.

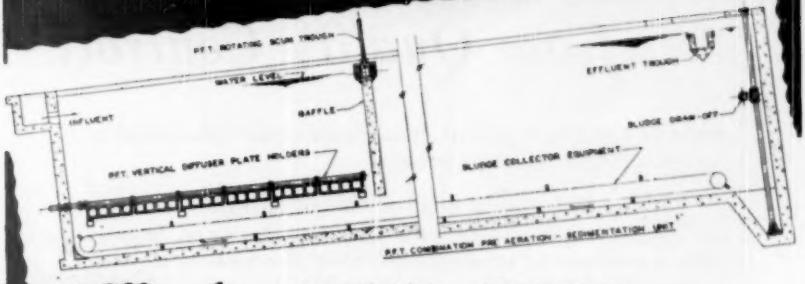
L. R. SETTER

**Safety Criteria in Radioactive Water Monitoring.** BY H. A. C. MCKAY AND G. N. WALTON. *Nucleonics* **5**, 2, 12 (1949).

The principles involved in assessing the hazard of individual or mixed radioisotopes are mathematically formulated. Assumed permissible doses for particular isotopes are used to compute the hazard of mixed isotopes subjected to a counting and sample preparation technique.

L. R. SETTER

# PFT PRE-AERATION

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**3 . . . IMPROVES SETTLING**

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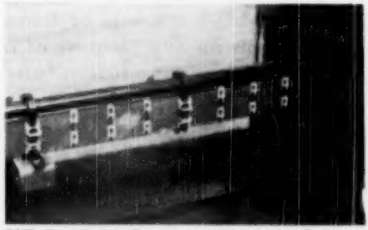
Recent PFT Preaeration equipment installations include: Marshfield, Wis.; San Leandro, Calif.; and Stockton, Calif. The North Point Plant for the City of San Francisco, for which contracts were recently awarded, also incorporates PFT preaeration equipment. Write for details.



PFT Preaeration Equipment in Aeration-Sedimentation tank at Sewage Treatment Plant of the Central Contra Costa Sanitary District, Walnut Creek, Calif.—Clyde C. Kennedy, Consulting Engineers.

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# *Who benefits from Quality Control?*

**What is Quality Control? What does it do? How does it function? Whom does it benefit?**

**First and foremost, a quality control operation benefits the customer. It also benefits the manufacturer. It provides assurance to management that the quality level of production is equal to, and generally in excess of, the standard specification.**

**Take us, for example. We manufacture cast iron pressure pipe in accordance with quality control specifications that are more comprehensive and exacting than the accepted technical specifications or customer's specifications under which pipe is purchased.**

**The first step in Quality Control is that of establishing company standards for both process methods and the physical and chemical properties of the product.**

**The next, backing-up step is establishing inspection procedures using statistical sampling techniques. These procedures extend from raw materials to finished product.**

**The final step is to have our Quality Control Dept. establish a group of facts in statistical form and analyze them for the purpose of removing quality standards from the realm of *opinion* into that of *organized facts*.**

**Production testing laboratories in our various plants are the tools for evaluating these quality standards.**

## U. S. PIPE & FOUNDRY CO.

General Offices, Burlington, N. J.

# How to beat a legal "threat" on WASTE DISPOSAL

WITH STATE AFTER STATE now imposing legal restrictions on industrial waste disposal, you may be faced with this problem quite suddenly. Only by starting to gather complete data *now* can you be prepared for necessary action when that time comes.

Foxboro has prepared a concise, informative bulletin on how to conduct a waste disposal survey. Based on specialized knowledge and long experience, this bulletin outlines the simple steps you can take to avoid hasty, last-minute plans. It shows how a careful, unhurried survey *now* can easily provide the facts on day-to-day quantities, concentrations, and constituents, so essential to efficient planning.

Send for a copy of "Waste Disposal Surveys", the first bulletin in Foxboro's series on Industrial Waste Disposal. Write **The Foxboro Company, 182 Neponset Avenue, Foxboro, Mass., U. S. A.**

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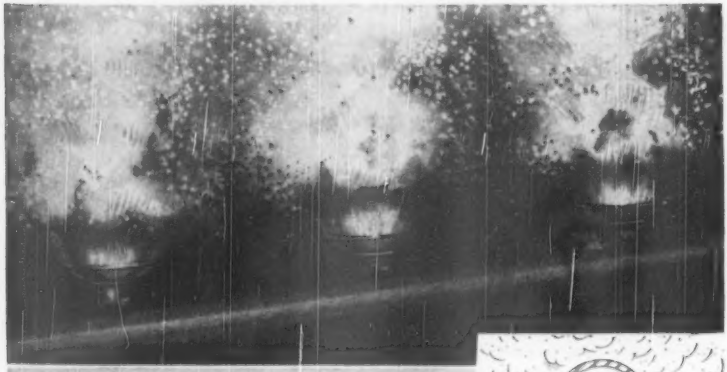

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Transite Sewer Pipe is made of asbestos, cement and silica by a special method of manufacture which develops high, uniform strength and resistance to corrosion. It is available in four strength classes in sizes to 36". This permits selection of the pipe best suited to trench conditions, frequently eliminates the need for concrete cradles.

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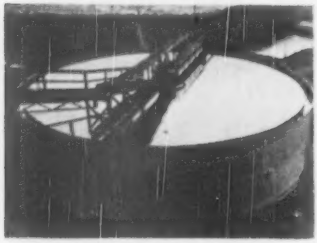

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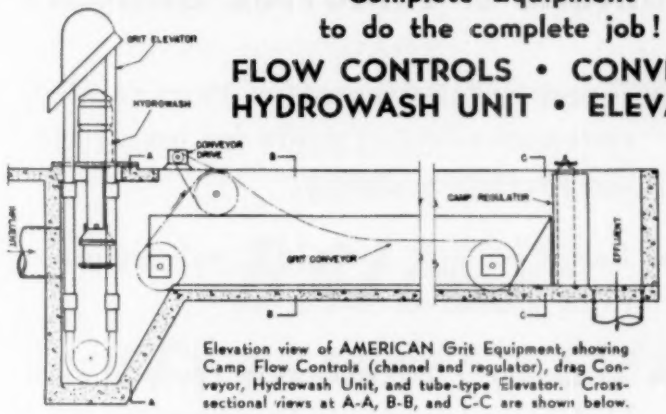


Elevation view of AMERICAN Grit Equipment, showing Camp Flow Controls (channel and regulator), drag Conveyor, Hydrowash Unit, and tube-type Elevator. Cross-sectional views at A-A, B-B, and C-C are shown below.

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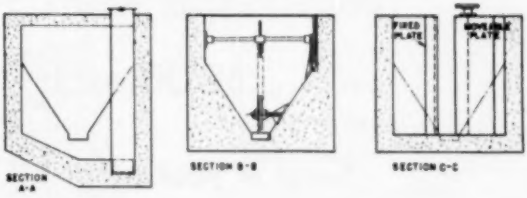


**FLOW CONTROLS**—exclusive Camp Control Section and Regulator maintain constant optimum velocity for effective grit settling, regardless of rate of flow through plant. Velocity can be easily and instantly adjusted to meet changing conditions.

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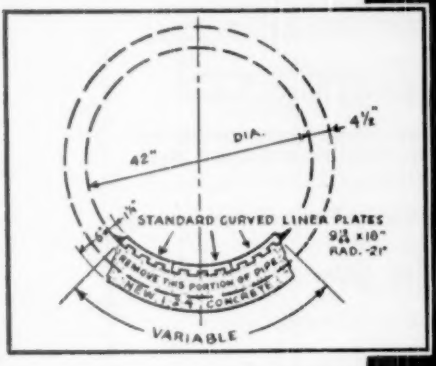

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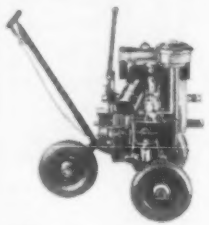

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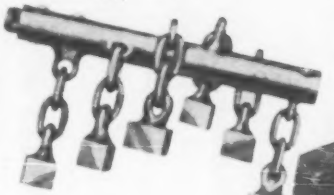

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